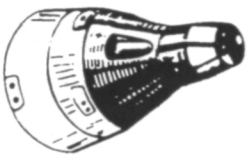
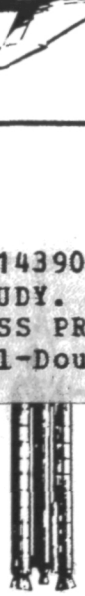
DRA





HIGH VALUE

SPACE SHUTTLE

LOW COST

(ASA-CR-143900) SPACE SHUTTLE PHASE B YSTEM STUDY. PART 2(A): ORBITER DETAILS. ETAIL MASS PROPERTIES REPORT Final Report (cDonnell-Douglas Corp.) 471 p

N75-76040

Unclas
00/98 17884

ONNELL DOUGLAS CORPORATION

MARTIN MARIETTA DENVER DIVISION

TRW SYSTEMS GROUP

PAN AM

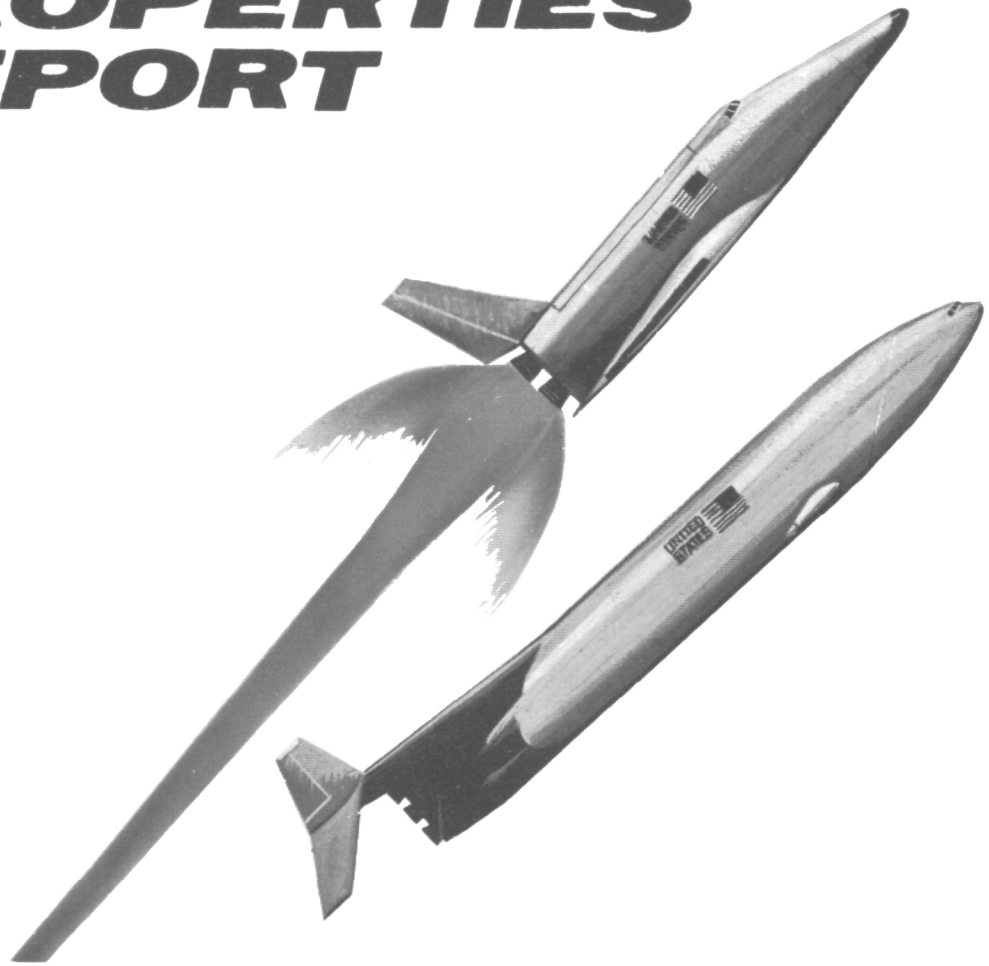
REPORT MDC E0377
30 JUNE 1971

Space Shuttle System

PHASE B STUDY FINAL REPORT

Part II (A)
Orbiter Details

DETAIL MASS PROPERTIES REPORT



SUBMITTED UNDER
NASA CONTRACT NO. NAS 8-26016
DRD MA016M- DRL LINE ITEM 23

MCDONNELL DOUGLAS CORPORATION
MARTIN MARIETTA DENVER DIVISION
PAN AM
TRW SYSTEMS GROUP

VOLUME II

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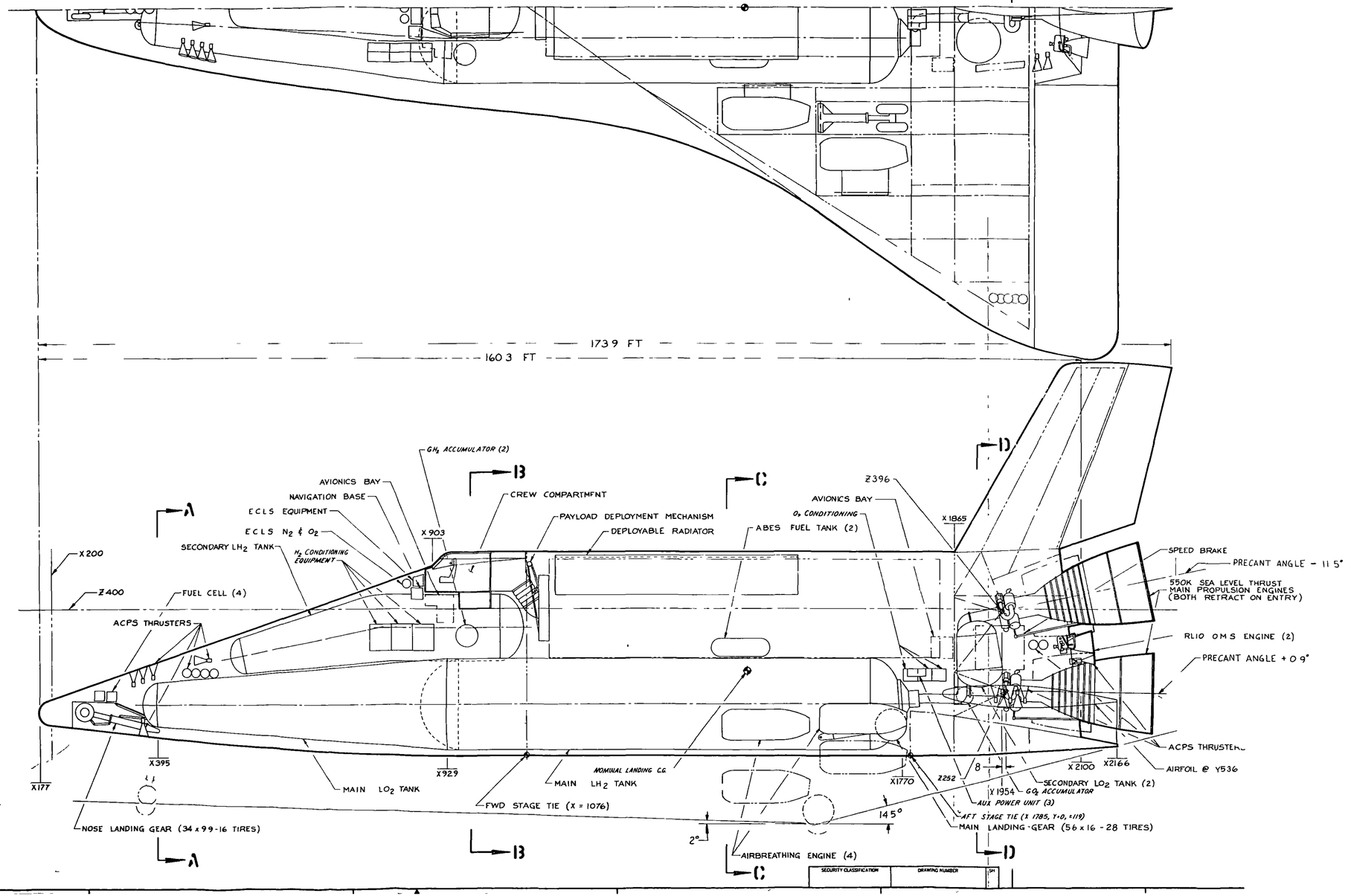
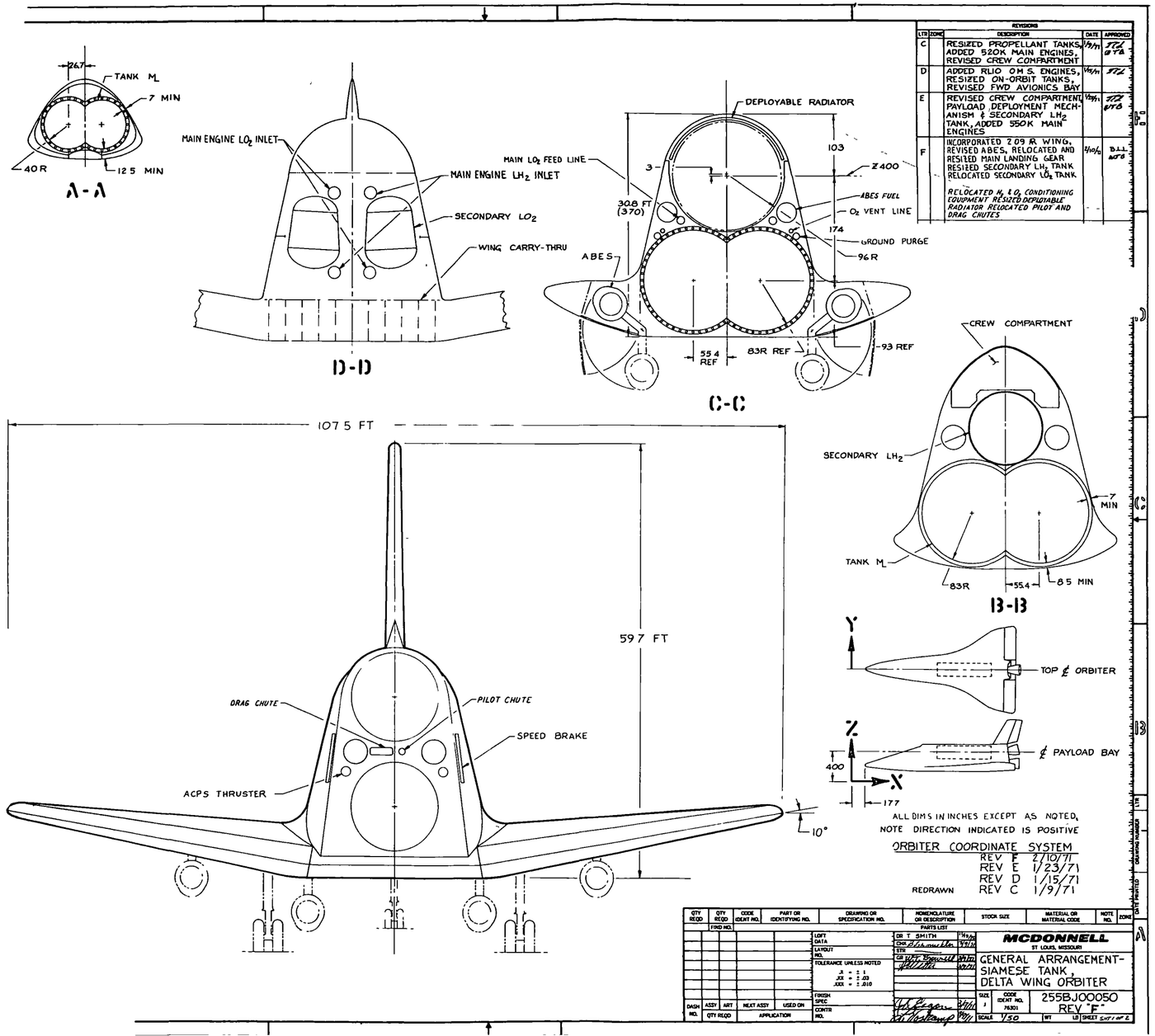
1.0 Introduction - This document is devoted to a detail derivation and substantiation of the analysis vehicle weights, and therefore a justification of the weights quoted throughout the Phase B Space Shuttle contract. The substantiation is done by using a detail component analysis for the various elements which comprise the orbiting vehicle. In the structural area, for example, we have computed weight based upon material gages provided by the strength group while in the system area we have taken a schematic and weighed each component on the schematic. Component weights in the systems area have been either vendor supplied or interpolated from plots of historical data points. By taking the "bottoms-up" approach we can substantiate that the data which has been generated throughout the study from generally a "top-down" technique is adequate for the program with its current Phase B status.

The "analysis" vehicle is reported in this document and a general arrangement drawing of the vehicle is shown in Figure 1-1. It is similar to the vehicle reported in the eighth month data dump and MP-8A, DRL 23-01. A group weight summary for this orbiter is shown in Figure 1-2 for each of the three missions. However, throughout this document we will concentrate on the easterly mission and show differences for alternate missions where they exist. A second group weight summary, Figure 1-3, also shows the percent of the weight group which is estimated or calculated. For this purpose we have said that a calculated weight is obtained from analysis done by other technologies while estimated weight is derived by empirical weight estimating relations. Vendor supplied data is considered calculated weight. This definition is different than the traditional definition of calculated, estimated, actual weight but has been done at the direction of and for additional insight by the NASA.

Section 2. of this volume presents the substantiating data for each of the first generation code groups. Each section begins with a detail weight listing which serves as a table of contents for the section. Then an illustration of the system follows with the monthly mass properties reporting format behind the illustration. The detail listing will have data underlined which will correspond to the monthly reporting format. The remainder of each section will then be devoted to showing the analysis and substantiating data for each weight shown in the detailed listing.


1739 FT
1603 FT
GH2 ACCUMULATOR (2)
AVIONICS BAY
NAVIGATION BASE
ECLS EQUIPMENT
ECLS N2 & O2
SECONDARY LH2 TANK
H2 CONDITIONING EQUIPMENT
CREW COMPARTMENT
PAYLOAD DEPLOYMENT MECHANISM
DEPLOYABLE RADIATOR
ABES FUEL TANK (2)
AVIONICS BAY
O2 CONDITIONING
Z396
X1865
X903
X200
Z400
FUEL CELL (4)
ACPS THRUSTERS
SPEED BRAKE
PRECANT ANGLE - 11.5°
550K SEA LEVEL THRUST MAIN PROPULSION ENGINES (BOTH RETRACT ON ENTRY)
RL10 OMS ENGINE (2)
PRECANT ANGLE + 0.9°
ACPS THRUSTERS
AIRFOIL @ Y536
X177
X395
X929
X1770
Z252
8
X2100
X2166
MAIN LO2 TANK
MAIN LH2 TANK
NOMINAL LANDING CG
FWD STAGE TIE (X = 1076)
SECONDARY LO2 TANK (2)
X1954
GO2 ACCUMULATOR
AUX POWER UNIT (3)
AFT STAGE TIE (X 1785, Y-0, ±119)
145°
2°
NOSE LANDING GEAR (34 x 9.9-16 TIRES)
MAIN LANDING GEAR (56 x 16 - 28 TIRES)
AIRBREATHING ENGINE (4)
A
B
C
D



1–2 Continued

FIGURE 1-2
ANALYSIS VEHICLE, ORBITER

GROUP WEIGHT SUMMARY

CONFIGURATION | BY | DATE

CODE	SYSTEM	A	B	C	D	E	F	G	H
1	WING GROUP	31587			31587			31587	
2	TAIL GROUP	5104			5104			5104	
3	BODY GROUP	55500			55500			55500	
4	INDUCED ENVIR PROTECTION	32847			32847			32847	
5	LANDING, RECOVERY, DOCKING	10551			10551			10551	
6	PROPULSION-ASCENT	26637			26637			26637	
7	PROPULSION-CRUISE	574			15273			574	
8	PROPULSION-AUXILIARY	11877			11877			11877	
9	PRIME POWER	2272			2272			2272	
10	ELECT CONVER & DISTR	1303			1303			1303	
11	HYDRA CONVER & DISTR	2760			2760			2760	
12	SURFACE CONTROLS	4901			4901			4901	
13	AVIONICS	4588			4588			4588	
14	ENVIRONMENTAL CONTROL	7849			7849			7849	
15	PERSONNEL PROVISIONS	430			430			430	
16	RANGE SAFETY & ABORT	0			0			0	
17	BALLAST	0			0			0	
18	GROWTH/UNCERTAINTY	25363			21718			23086	
19									
	SUBTOTAL (DRY WEIGHT)	224143			235197			221866	
20	PERSONNEL	626			626			626	
21	CARGO	65000			25000			40000	
22	ORDNANCE	0			0			0	
23	RESIDUAL FLUIDS	4001			4205			4001	
24									
	SUBTOTAL (INERT WEIGHT)	293770			265028			266493	
25	RESERVE FLUIDS	13118			14619			16178	
26	IN FLIGHT LOSSES	9788			9788			9788	
27	PROPELLANT-ASCENT	526257			526434			548927	
28	PROPELLANT-CRUISE	0			1140			0	
29	PROPELLANT-MANEUV/ACS	17510			28980			12022	
30									
	TOTAL (GROSS-WEIGHT) LB.	860443			845989			853408	

DESIGNATORS

EVENTS
A 65K EASTERLY MISSION
B
C
D 25K, 55° MISSION W/ABES
E
F
G 40K POLAR MISSION
H

NOTES & SKETCHES

GROUP WEIGHT SUMMARY (EASTERLY MISSION)

CONFIGURATION: DELTA ORBITER | BY: | DATE: 17 June 1971

CODE	SYSTEM	A	B	C	D	E	F	G	H
1	WING GROUP	31587		26245	83.1		5342	16.9	
2	TAIL GROUP	5104		4544	89.0		560	11.0	
3	BODY GROUP	55500		45661	82.3		9839	17.7	
4	INDUCED ENVIR PROTECTION	32847		29861	90.9		2986	9.1	
5	LANDING, RECOVERY, DOCKING	10551		0	0		10551	100.0	
6	PROPULSION-ASCENT	26637		21259	79.8		5378	20.2	
7	PROPULSION-CRUISE	574	*	261	45.5		313	54.5	
8	PROPULSION-AUXILIARY	11877		7964	67.1		3913	32.9	
9	PRIME POWER	2272		0	0		2272	100.0	
10	ELECT CONVER & DISTR	1303		0	0		1303	100.0	
11	HYDRA CONVER & DISTR	2760		832	30.1		1928	69.9	
12	SURFACE CONTROLS	4901		130	2.7		4771	97.3	
13	AVIONICS	4588		2514	54.8		2074	45.2	
14	ENVIRONMENTAL CONTROL	7849		5377	68.5		2472	31.5	
15	PERSONNEL PROVISIONS	430		159	37.0		271	63.0	
16	RANGE SAFETY & ABORT	0		0	0		0	0	
17	BALLAST	0		0	0		0	0	
18	GROWTH/UNCERTAINTY	25363		25363	100		0	0	
19									
	SUBTOTAL (DRY WEIGHT)	224143		170170	75.9		53973	24.1	
20	PERSONNEL	626		234	37.4		392	62.6	
21	CARGO	65000		65000	100		0	0	
22	ORDNANCE	0		0	0		0	0	
23	RESIDUAL FLUIDS	4001		4001	100		0	0	
24									
	SUBTOTAL (INERT WEIGHT)	293770		239405	81.5		54365	18.5	
25	RESERVE FLUIDS	13118		13118	100		0	0	
26	IN FLIGHT LOSSES	9788		9788	100		0	0	
27	PROPELLANT-ASCENT	526257		526257	100		0	0	
28	PROPELLANT-CRUISE	0		0	0		0	0	
29	PROPELLANT-MANEUV/ACS	17510		17510	100		0	0	
30									
	TOTAL (GROSS-WEIGHT) LB.	860443		806078	93.7		54365	6.3	

DESIGNATORS.

EVENTS
A Easterly Mission
B
C Pounds Calculated
D Percent Calculated
E
F Pounds Estimated
G Percent Estimated
H

NOTES & SKETCHES·

*On Resupply Mission 73.3% is calculated, 26.7% estimated on cruise propulsion.

Section 3. of this volume includes references on supporting data and a cross-reference coding of the weight. The cross-reference has been requested specifically by the NASA with an aim toward providing additional visibility beyond the functional weight format being used in this report in other sections. For example, the landing gear doors are coded in two places - in the wing for main gear and in the body for nose gear. These will be broken out separately so that all gear related weight will be accounted for. A summary of this data is shown in Figure 1-4.

Three appendices (A, B and C) are included to provide the data files for the easterly, resupply and polar missions. These files include detail build-up of components to obtain weight, center-of-gravity, moment and product of inertia. Also included in Appendix A is a mass distribution for the landing, injection, 50% burn and launch weight.

Some confusion has arisen throughout the study on the McDonnell Douglas terminology and weight estimating philosophy. For this reason, a few definitions are in order.

1. Nominal Weight - The most probable weight based upon the specific requirements and criteria. The Nominal includes contingency for in-scope design development changes. Specific allowances for "growth" are included to the extent specified in the requirements and criteria.
2. Contingency - That weight which must be added to an estimate to account for lack of detail in the system and/or its development state at the time of estimate and/or the type of method used to make the estimate.
3. Growth - Changes in weight due to revisions in requirement and criteria, or concept, and/or solution of major unanticipated development problems (normally out-of-scope changes which involve cost revisions).
4. Uncertainty - The variation of weight (or other mass property about the nominal due to the routine but random nature of design development problems, manufacturing tolerances, and the natural variations of possible design approaches.

On the shuttle program the latter two terms have been added as though they were one item.

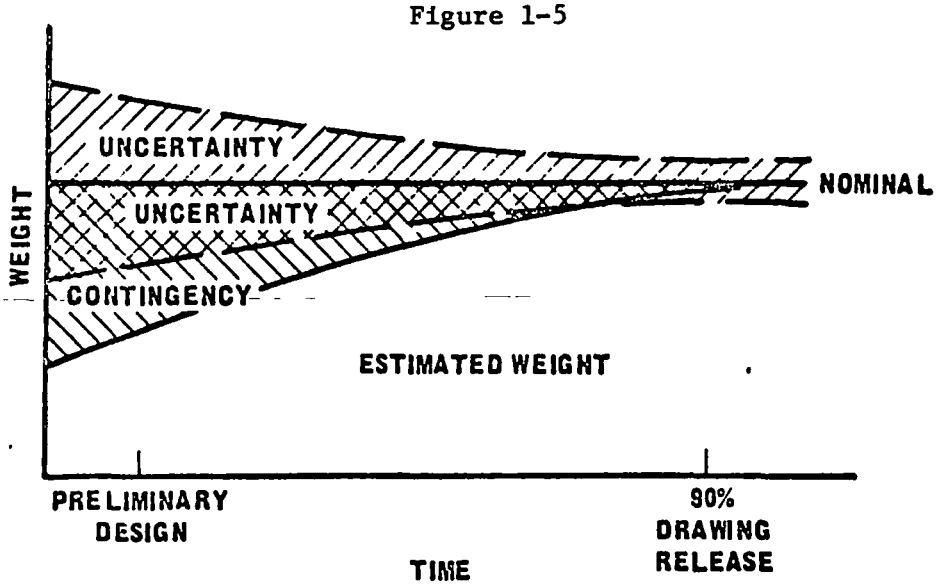
The above definitions are illustrated graphically in Figure 1-5. Note how the elements fit together with the predicted value for weight being composed of three elements - the (1) estimated weight based upon current design criteria

FIGURE 1-4
SUMMARY CROSS-CODING OF WEIGHT

GROUP	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	18.0	20.0	21.0	23.0	25.0	26.0	27.0	28.0	29.0
1.0 WING	31587			5272	518		1768									2872								
2.0 TAIL		5104		731												464								
3.0 BODY			55500	1996	330	21918					20					5046								
4.0 IND. ENV. PROT.	8330		21181	32847		1886										2986								
5.0 LAND, DOCK, SEP.	6624		1603		10551											788								
6.0 PROP - ASCENT						26637				96	564					1010								
7.0 PROP - CRUISE							574			110						62								
8.0 PROP - AUX.				1571				11877		56	22					1210								
9.0 PRIME PWR.									2272							296								
10.0 ELECT. CONV & DIST										1303						170								
11.0 HYD. CONV & DIST										104	2760					714								
12.0 SURFACE CONT.	2582	663								62	4901	4901				458								
13.0 AVIONICS										652		217	4588			599								
14.0 ENVIR. CONT.	1097	63		3980	572	1103	415			914	272	236		7849		648								
15.0 PERSON. PROV.															430	20	430							
18.0 GROWTH/UNCER.																25363								
20.0 PERSONNEL																	626							
21.0 CARGO																		65000						
23.0 RESIDUAL FLUID					126	737		1430			1087	279		595					4001					
25.0 RESERVE FLUIDS						6486		6382			148			102						13118				
26.0 INFLIGHT LOSSES						6467		1552	1445		805			324							9788			
27.0 PROPELLANT-ASC.						526257																526257		
28.0 PROPELLANT-CRUISE																							0	
29.0 PROP. - MANEU/ACS								17510																17510
TOTAL	50220	5830	78284	46397	12097	591491	2757	38751	3717	3297	10579	5633	4588	8870	430	42706	1056	65000	4001	13118	9788	526257	0	17510

plus the (2) contingency based upon the type of method being used in the estimate plus or minus the (3) uncertainty based upon a statistical addition of system variances.

Figure 1-5



Nominal weight is the most probable weight. It is the weight which we are trying to forecast for purposes of design evaluation. It is composed of an estimated weight plus contingency. Estimated weight is based upon a multitude of design criteria and combinations of criteria as they can best be evaluated at the current point in time. In addition to the design criteria items, there are items for which no criteria has been established, but as good weight engineers, we know will exist. These items must be included within nominal weight. Additionally, nominal weight should be developed in such a way that the in-scope design changes (within the constraint of minimum design criteria revision) may be accounted for.

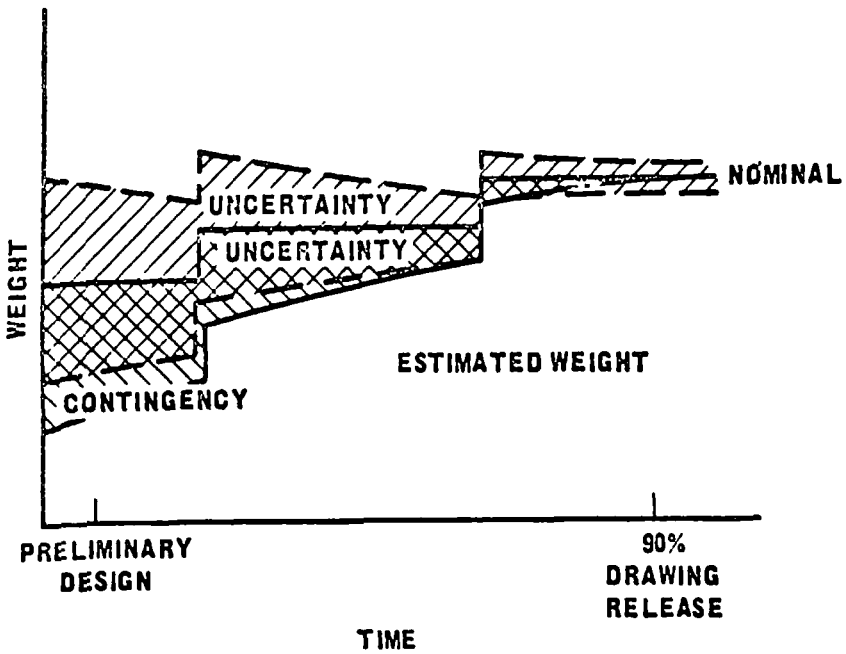
Contingency is that weight which must be added to an estimate to obtain a nominal weight. Contingency will include such things as an allowance for gage tolerances in sheet metal or machined parts, and/or weight from correlation factors, and/or an assigned weight based upon the type of system and its current development state.

On some of our estimates we are computing weights based upon analytical models of the system. We find that this analytical approach gives proper trends for the critical system parameters, but the model does not account for all the system weight. By using the model on existing hardware, we can plot estimated versus actual

weights. The correlating factor which results from this plot accounts for Contingency. It again is that difference between estimated weight and Nominal weight.

The definition of Growth is not shown in Figure 1-5 as illustrated by the horizontal line for Nominal Weight. Recall that growth is that increase (or decrease) in the weight that results from a change in requirements and criteria, or concept, and/or the solution of major unanticipated development problems. The contractor has established a set of estimates based upon a number of criteria. When these criteria change, the weight changes. Generally the customer wants more performance, and this is supplied at the expense of weight. In this more typical case, Figure 1-5 is transformed into Figure 1-5A. The steps in the nominal weight in Figure 1-5A have occurred due to changes in criteria. This is Growth. Growth becomes a problem only when it exceeds the current capability of the vehicle to accept that Growth and still maintain performance at an acceptable level. (In the spacecraft business this implies that spacecraft weight will "grow" with booster capability as evidenced by the Mercury and Gemini flights.)

Figure 1-5A



Uncertainty is the variation of a mass property about the nominal value for the mass property. It may be either plus or minus. Both Figures 1-5 and 1-5A show the graphic definition of Uncertainty as a function of time. In general, the Uncertainty begins as a wide band about the nominal at the early estimate stage. As time passes more and more is known about the vehicle design and the

Uncertainty becomes less. However, even at weighing there is an Uncertainty - in fact - two Uncertainties. One is in the weighing system when a single ship is weighed. The other Uncertainty is due to variations between "identical" ships.

The shuttle program has combined the items growth and uncertainty. At the beginning of Phase B a target value for the end of Phase B was set at ten percent of dry weight less ascent engines as an adequate allowance based upon previous McDonnell Douglas historical product trends. (This has since been changed to ten percent less ascent engines and less cruise engines.) This ten percent then is an allowance to account for requirement changes, unanticipated developed problems and to improve the probability that the quoted nominal weight can be met.

Even though we have attempted to account for all items in our analysis, the current definition of the analysis vehicle is not 100% complete, and, hence, we have undoubtedly omitted some items from the weight. For example, numerous cut-outs will exist in the TPS for access provision but not all of these cut-outs have been analyzed. Rather than ignore the omissions and other routine design development problems we have chosen to include a contingency in each of our system weights.

Contingency may be determined in three separate ways - each tied to actual hardware to insure that proper values are calculated. These methods can be described as:

a. Historically Derived - This method collects data from previous studies which resulted in hardware. The derived contingencies are calculated based upon the difference between initial estimate and final hardware. The initial estimate on the various weight item are made at varying stages of design, hence a table can be generated showing a variation of contingency with design status and design category or component. The recommended contingency table for shuttle usage is shown in Figure 1-6. This table has been used as a guide and at best subjective interpolation is required on any given system.

b. Semi-Empirically Derived - Contingency factors may also be generated by establishing a model and then comparing the model results to actual weights. The ratio between the actual hardware weight and the model weight yields the contingency factor which must be applied to the model to account for the lack of detail in the model technique. This technique is employed on the aerosurface estimating method where model weights are

scaled up 20% to attain a nominal weight.

c. *Similar Analysis Method* - Contingency factors can also be determined by applying an analysis technique to actual hardware and comparing the analysis weight against the hardware weight. For example, knowing SIVB loading and pressure compute sidewall thickness at various body stations using $\sigma = \frac{Mc}{I} + \frac{PR}{t}$. The weight derived in this manner can be compared to the actual hardware weight to derive the necessary contingency to yield realistic weight.

Figure 1-6
Historically Derived Contingencies

Design Status	Design Category						
	Structure & TPS	Non-Electrical Equipment	Electrical				
			Batteries & Fuel Cells	Wire & Instrumentation	Motors, Electronics, Pwr. Req 0-10 lbs	11-30 lbs	31+ Lbs
Estimated Weight							
o Conceptual	28	33					
o Layout	15	15	20	100	30	20	15
o Vendor Spec.		9					
Calculated (Pre-Qual.)							
o Detail Drwg.	5	5	10	25	20	15	10
o Assembly Drwg.							
o Wiring Diag.							
o Drwg. Changes							
Calculated (Post-Qual.)							
o Detail Drwg.	3	3	5	5	10	5	5
o Assembly Drwg.							
o Wiring Board							
o Drwg. Change							
Actual Weights	0	0	0	0	0	0	0

DETAIL WEIGHT STATEMENT
WING GROUP

Item	Weight	Summary Index	Calculations Page No.
Wing Group	31587		
Basic Structure			
Torque Box	[14788]		2.1-15-52
Covering	(6338)	2.1-8	
Skin	3998	2.1-8	
Stringers	2340	2.1-8	
Spars	(2428)		
L.E. Spar	408	2.1-8	2.1-54-56
Aux. Front Spar	158	2.1-8	2.1-57-59
Aux. Rear Spar	512	2.1-9	2.1-57-59
Front Spar	672	2.1-9	2.1-60-73
Mid Spar	404	2.1-9	2.1-60-73
Rear Spar	274	2.1-9	2.1-60-73
Ribs	(6072)		
Root Rib	1952	2.1-9	2.1-74-84
Rib 2	594	2.1-9	2.1-85-88
Rib 2A	100	2.1-9	
Rib 2B	150	2.1-9	
Rib 3	1408	2.1-9	2.1-89-92
Rib 3A	100	2.1-10	2.1-99-100
Rib 4	284	2.1-10	2.1-93-95
Rib 4A	218	2.1-10	2.1-93-95&99-100
Rib 5	426	2.1-10	2.1-96-98
Rib 5A	308	2.1-10	2.1-96-98
Rib 5B	136	2.1-10	2.1-93-95&99-100
Rib 5C	100	2.1-10	2.1-99-100
Rib 5D	70	2.1-11	2.1-99-100
Rib 6	60	2.1-11	2.1-99-100
Inb'd ACS	76	2.1-11	
Outb'd ACS	40	2.1-11	2.1-99-100
Carry Thru	[2735]		
Covering	(1726)		2.1-103-104
Skin	950	2.1-11	
Stringers	776	2.1-11	
Ribs	(1009)		
BL 0 Rib	123	2.1-11	2.1-105
BL 28 Rib	210	2.1-11	2.1-106
BL 55 Rib	236	2.1-12	2.1-107
BL 85 Rib	212	2.1-12	2.1-108
BL 119 Rib	228	2.1-12	2.1-109
Leading Edge	[5272]	2.1-12	2.4-5
Carbon-Carbon L.E.	(1636)		
Columbium L.E.	(510)		
Columbium Strake	(3126)		

Item	Weight	Summary Index	Calculation Page No.
Secondary Structure			
Doors	[2286]	2.1-12	2.1-110
MLG Door Provisions	(518)		
Fwd ABES Door Provision	(884)		
Aft ABES Door Provision	(884)		
Control Surfaces			
Elevon	[3634]	2.1-13	2.1-115
Covering	(2066)		2.1-116-117
Skin	1496		
Stringers	570		
Front Spar	(220)		2.1-118-119
Ribs	(742)		2.1-120&121
Intercostals	(52)		2.1-120
Flipper Doors	(370)		2.1-119
Hinges	(184)		
Contingency	[2872]		2.1-4

DETAIL WEIGHT SUBSTANTIATION
WING GROUP

1. WING GROUP	CARRY THROUGH	EXPOSED SURFACE		31587
BASIC STRUCTURE	(2735)	(20060)	22795	
TORQUE BOX	2735	14788		
LEADING EDGE		5272		
TRAILING EDGE		INC'L		
SECONDARY STRUCTURE			2286	
MAIN GEAR DOOR PROVISIONS		518		
ABES DOOR PROVISIONS		1768		
CONTROL SURFACES	SURFACE	SUPT/MECH	3634	
ELEVON	3634			
CONTINGENCY			2872	

THE WING GROUP IS BROKEN DOWN INTO THE FOLLOWING 5 ANALYSIS SYSTEMS: LEADING EDGE
FWD WING (FWD OF FRONT CARRY THRU SPAR)
TORQUE BOX
CARRY THRU
ELEVON

THE TORQUE BOX AND FWD WING ARE SUMMARIZED TOGETHER UNDER TORQUE BOX. THE REMAINING ITEMS ARE HANDLED SEPARATELY. THE PRIMARY STRUCTURAL MATERIAL FOR THE WING IS 6-6-2 TITANIUM FOR MECHANICALLY ATTACHED COMPONENTS SUCH AS WING SKINS, BORON-ALUMINUM COMPOSITES ARE USED FOR STRINGERS, AND 6-4 TITANIUM IS USED FOR WELDED ITEMS SUCH AS RIBS AND SPARS (CORRUGATED WEBS WELDED TO CAPS).

THE GEOMETRY IS DEFINED BY DWG 255B1000506, THE STRENGTH REQUIRED GAGES AND CROSS-SECTIONAL AREAS ARE DEFINED IN REPORT NO E0308, SECTION 2.3.1.3 FOR THE EXTERNAL LOADS DEFINED IN

REPORT NO E0308, SECTION 2.2.6-15. THE REQUIRED SIZES ARE DUPLICATED AND NOTED WITH THE INDIVIDUAL WEIGHT CALCULATION.

THE WING GROUP WEIGHTS AND INERTIAS ARE SUMMARIZED ON PAGES 2-5 THRU -7 WITH THE FOLLOWING 6 PAGES BEING THE DETAIL MASS PROPERTIES COMPUTER INPUT FOR WEIGHT, CG, AND MOMENT OF INERTIA.

THE WEIGHTS ARE ENTIRELY DERIVED FROM [illegible] CALCULATIONS WITH THE EXCEPTION OF THE MLG AND ABES DOOR PROVISIONS WHICH ARE EMPERICALLY DERIVED

THE LEADING EDGE WEIGHTS ARE CARRIED IN THE WING SECTION FOR SUMMARIZING PURPOSES ONLY. THE WEIGHTS ARE DERIVED IN DETAIL IN THE THERMAL PROTECTION SECTION (2.4-5).

NON OPTIMUMS ARE DERIVED FOR RELATIVELY SIMPLE TYPES OF CONSTRUCTION SUCH AS SURFACE SKINS AND STRINGERS. FOR COMPLEX ITEMS SUCH AS SPARS THE NON OPTIMUM IS 28% ON THE IDEAL GAGES TO ALLOW FOR ROUTING DEVELOPMENT AND MANUFACTURING PROBLEMS TEN PERCENT OF THIS TOTAL IS ASSUMED FOR INSTALLATION

AS NOTED IN THE INTRODUCTION, SECTION 1.0, THE WEIGHT CONTINGENCY HAS A VARIATION FROM 8% ON CONCEPTUAL WORK TO 15% ON LAYOUT WORK TO 5% ON CALCULATIONS OF DETAIL DRAWINGS. THE STRUCTURAL WEIGHT ANALYSIS PRESENTED IN THE FOLLOWING PAGES IS FURTHER ADVANCED THAN THE LAYOUT PHASE BUT DOES NOT HAVE THE DEPTH REQUIRED FOR DETAIL DRAWING CALCULATIONS. CONSEQUENTLY A CONTINGENCY OF 10% IS APPLIED TO ALL STRUCTURAL SUBSYSTEMS.

I

MASS PROPERTIES SUMMARY 06/09/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
					(SLUG-FEET SQ./1000.)		
SKIN	3998.	1809.	0.	203.	84.	10.	91.
					0.	0.	0.
STGR	2340.	1782.	0.	211.	46.	6.	50.
					0.	0.	-0.
COVER	6338.	1799.	0.	206.	130.	17.	141.
					0.	0.	-0.
L.E.SPAR	408.	1675.	0.	221.	15.	2.	17.
					0.	0.	0.
AUX FRONT	158.	1425.	0.	181.	1.	0.	1.
					0.	0.	-0.
AUX REAR	512.	1600.	0.	191.	7.	0.	7.
					0.	0.	0.
FRONT SPAR	672.	1785.	0.	196.	6.	0.	6.
					0.	0.	0.
MID SPAR	404.	1865.	0.	211.	4.	0.	4.
					0.	0.	-0.
REAR SPAR	274.	2009.	0.	211.	4.	0.	4.
					0.	0.	0.
SPARS	2428.	1743.	0.	202.	37.	14.	51.
					0.	0.	0.
ROOT RIB	1952.	1711.	0.	181.	9.	9.	18.
					0.	0.	0.
RIB 2	594.	1600.	0.	185.	4.	1.	4.
					0.	0.	0.
RIB 2A	100.	1895.	0.	182.	1.	0.	1.
					0.	0.	0.
RIB 2B	150.	1900.	0.	183.	1.	0.	1.
					0.	0.	-0.
RIB 3	1408.	1667.	0.	183.	17.	3.	20.
					0.	0.	0.
RIB 3A	100.	1895.	0.	184.	1.	0.	2.
					0.	0.	0.
RIB 4	284.	1704.	0.	185.	5.	2.	7.
					0.	0.	-0.
RIB 4A	218.	1784.	0.	185.	5.	1.	5.
					0.	0.	-0.
RIBS	426.	1856.	0.	198.	11.	1.	13.
					0.	0.	0.
RIB 5A	308.	1920.	0.	201.	9.	0.	9.
					0.	0.	0.
RIB 5B	136.	1841.	0.	206.	5.	0.	5.
					0.	0.	-0.
RIB 5C	100.	1867.	0.	216.	4.	0.	4.

L

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TS841-B05

1 MASS PROPERTIES SUMMARY 06/09/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X	Y (INCH)	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
L					(SLUG-FEET SQ./1000.)		
					0.	0.	0.
RIB 5P	70.	1940.	0.	223.	3.	0.	4.
					0.	0.	0.
RIB 6	60.	1930.	0.	227.	3.	0.	3.
					0.	0.	0.
INBD OMS	76.	1969.	0.	230.	5.	0.	5.
					0.	0.	0.
OUTBD OMS	40.	1994.	0.	230.	3.	0.	3.
					0.	0.	0.
RIBS	6029.	1738.	0.	185.	87.	30.	117.
					0.	0.	1.
TORQUE BOX	14788.	1765.	0.	198.	254.	64.	311.
					0.	0.	0.
CT SKIN	950.	1897.	0.	176.	1.	1.	2.
					0.	0.	0.
CT STGR	776.	1897.	0.	176.	1.	1.	2.
					0.	0.	0.
COVER	1726.	1897.	0.	176.	3.	2.	4.
					0.	0.	0.
PLO RIB	123.	1897.	0.	176.	0.	0.	0.
					0.	0.	0.
PL 25 RIB	210.	1897.	0.	176.	0.	0.	0.
					0.	0.	0.
PL 55 RIB	236.	1897.	0.	176.	0.	0.	0.
					0.	0.	0.
PL65 RIB	210.	1897.	0.	176.	0.	0.	0.
					0.	0.	0.
PL113 RIB	226.	1897.	0.	176.	1.	0.	1.
					0.	0.	0.
RIB	1009.	1897.	0.	176.	1.	0.	2.
					0.	0.	0.
CARRY THRU	2735.	1897.	0.	176.	4.	2.	5.
					0.	0.	-0.
LEADING EDGE	5272.	1404.	0.	195.	120.	114.	234.
					0.	0.	2.
MLG DOORS	518.	1692.	0.	195.	4.	0.	4.
					0.	0.	0.
APES DOOR	1768.	1501.	0.	195.	23.	4.	27.

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TS896-90005

MASS PROPERTIES SUMMARY 06/09/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y (INCH)	Z (INCH)	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
					(SLUG-FEET SQ./1000.)		
					0.	0.	-0.
DOORS	2286.	1622.	0.	185.	27.	5.	32.
					0.	0.	-0.
SKIN	1496.	2087.	0.	197.	59.	1.	59.
					0.	0.	-0.
STGR	570.	2087.	0.	197.	22.	0.	22.
					0.	0.	-0.
COVER	2066.	2087.	0.	197.	82.	1.	82.
					0.	0.	-0.
SPAR	220.	2024.	0.	197.	9.	0.	9.
					0.	0.	0.
RIBS	742.	2059.	0.	197.	29.	0.	29.
					0.	0.	0.
INTERCSTL	52.	2087.	0.	197.	2.	0.	2.
					0.	0.	0.
DOORS	370.	2020.	0.	197.	15.	0.	15.
					0.	0.	0.
HINGES	184.	2021.	0.	197.	7.	0.	7.
					0.	0.	-0.
ELEVON	3634.	2067.	0.	197.	143.	2.	144.
					0.	0.	-0.
CONTINGENCY	2872.	1738.	0.	194.	0.	0.	0.
					0.	0.	0.
WING	31587.	1738.	0.	194.	549.	423.	962.
					0.	0.	4.

DETAIL INDEX

Item		Wt				Ref Pages
4.000	UPR TB SKIN	633.0	1880.	315.	221.	22-29 thru 44
5.000	UPR TB SKIN	633.0	1880.	-315.	221.	
6.000	UPR FW SKIN	367.0	1698.	249.	221.	22-45 - 52
7.000	UPR FW SKIN	367.0	1698.	-249.	221.	
8.000	LWR TB SKIN	579.0	1880.	315.	185.	22-15 - 28
9.000	LWR TB SKIN	579.0	1830.	-315.	185.	
10.000	LWR FW SKIN	420.0	1698.	249.	185.	22-45 — 52
11.000	LWR FW SKIN	420.0	1698.	-249.	185.	
12.000	SKIN	3178				
13.000	UPR TB STRG	344.0	1830.	315.	221.	22-2 -
14.000	UPR TB STRG	344.0	1830.	-315.	221.	
15.000	UPR FW STRG	487.0	1698.	249.	221.	22-15 -
16.000	UPR FW STGR	487.0	1698.	-249.	221.	
17.000	LWR TB STGR	196.0	1830.	315.	135.	22-2 -
18.000	LWR TB STGR	196.0	1830.	-315.	135.	
19.000	LWR FW STGR	143.0	1698.	249.	135.	22-45 -
20.000	LWR FW STGR	143.0	1698.	-249.	135.	
21.000	STGR	2345				
22.000	COVGR	6333				
23.000	WG SPHR	146.0	1600.	349.	221.	22-5 -
24.000	WG SPHR	146.0	1600.	-349.	221.	
25.000	H T SPHR	58.0	1865.	512.	221.	22-54 -
26.000	H T SPHR	58.0	1365.	-512.	221.	
27.000	LOX SPHR	52				
28.000	HUX RONT	79.0	1425.	192.	181.	22-57 -
29.000	HUX RONT	79.0	1425.	-192.	181.	
30.000	HUX RONT	153				
31.000	HUX RGHR	256.0	1600.	241.	191.	22-57 — 58
32.000	HUX RGHR	256.0	1600.	-241.	191.	

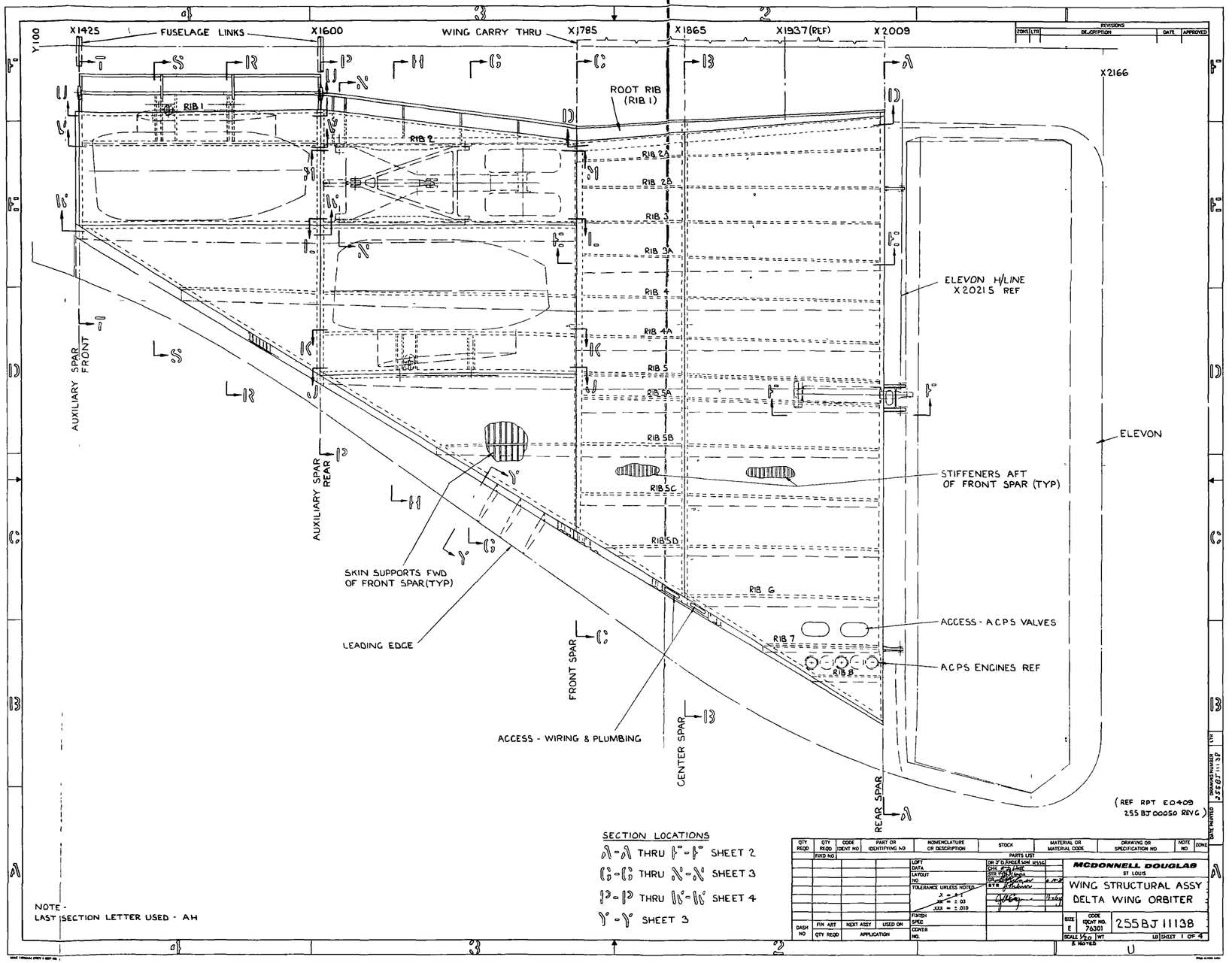
Item						Ref Pages	
33.000	AUX RCSR	512					
34.000	FRONT SPSR	336.0	1785.	190.	196.	2.2-60	- 63
35.000	RONT SPSR	336.0	1785.	-190.	196.		
36.000	RONT SPSR	672					
37.000	MID SPSR	202.0	1865.	200.	211.	2.2-64	-70
38.000	MID SPSR	202.0	1865.	-200.	211.		
39.000	MID SPSR	404					
40.000	RCSR SPSR	137.0	2009.	220.	211.	2.2-60	-73
41.000	RCSR	137.0	2009.	-220.	211.		
42.000	RCSR SPSR	274					
43.000	SPSRS	2428					
44.000	WD	568.0	1600.	140.	181.	2.2-80	- 84
45.000	WD	568.0	1600.	-140.	181.		
46.000	S T	408.0	1365.	155.	181.	2.2-74	- 79
47.000	S T	408.0	1865.	-155.	181.		
48.000	ROOT RID	1952					
49.000	RID 2	297.0	1600.	170.	185.	2.2-85	-88
50.000	RID 2	297.0	1600.	-170.	185.		
51.000	RID 2	594					
52.000	RID 2S	50.0	1895.	183.	182.	2.2-94	-100
53.000	RID 2A	50.0	1895.	-183.	182.		
54.000	RID 2S	100					
55.000	RID 2D	75.0	1900.	202.	183.	2.2-94	-100
56.000	RID 2D	75.0	1900.	-202.	183.		
57.000	RID 2D	150					
58.000	WD	654.0	1650.	240.	183.	2.2-89	-92
59.000	WD	654.0	1650.	-240.	183.		
60.000	S T	50.0	1895.	227.	183.	2.2-94	- 100
61.000	S T	50.0	1895.	-227.	183.		
62.000	RID 3	1408					

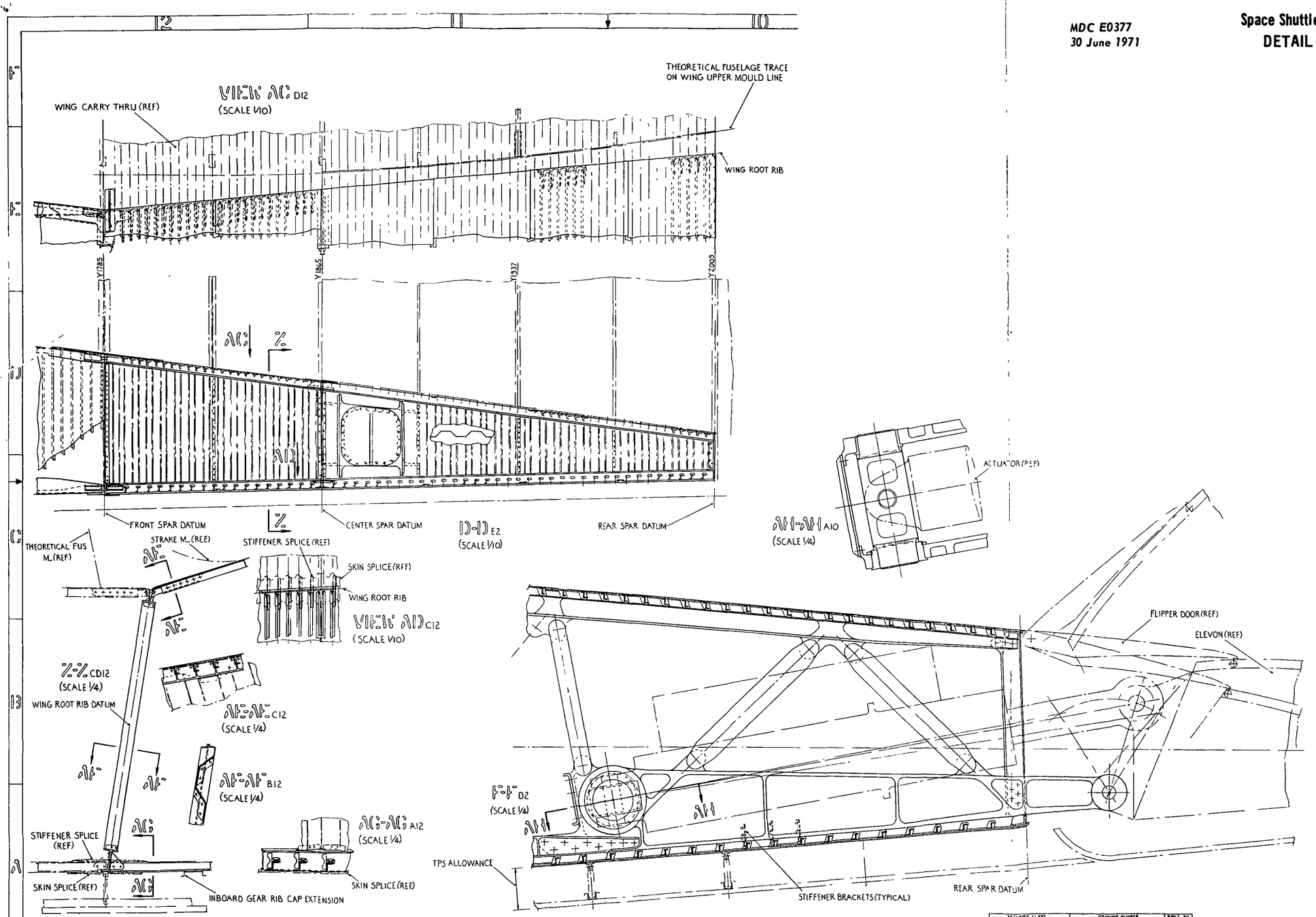
Item						REF PAGES
63.000	RIB 3H	50.0	1895.	260.	184.	2 2-99 -100
64.000	RIB 3H	50.0	1895.	-260.	184.	
65.000	RIB 3H	100				
66.000	WB	92.0	1600.	290.	185.	2 2-93 94
67.000	WB	92.0	1600.	-290.	185.	
68.000	H T	50.0	1895.	290.	185.	2.2-99 -100
69.000	H T	50.0	1895.	-290.	185.	
70.000	RIB 4	284				
71.000	WB	59.0	1690.	319.	185.	2 2-95
72.000	WB	59.0	1690.	-319.	185.	
73.000	H T	50.0	1895.	319.	185.	2.2-99 -100
74.000	H T	50.0	1895.	-319.	185.	
75.000	RIB 4H	218				
76.000	WB	59.0	1690.	349.	193.	2 2-95
77.000	WB	59.0	1690.	-349.	193.	
78.000	H T	154.0	1920.	349.	198.	2 2-96 - 99
79.000	H T	154.0	1920.	-349.	198.	
80.000	RIBS	426				
81.000	RIB 5H	154.0	1920.	364.	201.	2 2-96 - 99
82.000	RIB 5H	154.0	1920.	-364.	201.	
83.000	RIB 5H	308				
84.000	WB	23.0	1735.	401.	206.	2 2-95
85.000	WB	23.0	1735.	-401.	206.	
86.000	H T	45.0	1895.	401.	206.	2 2-99 -100
87.000	H T	45.0	1395.	-401.	206.	
88.000	RIB 5D	136				
89.000	WB	10.0	1755.	438.	216.	2 2-95
90.000	WB	10.0	1755.	-438.	216.	
91.000	H T	40.0	1895.	438.	216.	2 2-99 - 100
92.000	H T	40.0	1395.	-438.	216.	
93.000	RIB 5U	100				

Item					Ref Pages
94.000 RIB 5U	35.0	1840.	481.	223.	2.2-99 - 100
95.000 RIB 5U	35.0	1840.	-481.	223.	
96.000 RIB 5U	70				
97.000 RIB 6	30.0	1930.	512.	227.	2.2-99 - 100
98.000 RIB 6	30.0	1930.	-512.	227.	
99.000 RIB 6	60				
100.000 INBD ØMS	38.0	1969.	534.	230.	2.2-99 - 100
101.000 INBD ØMS	38.0	1969.	-534.	230.	
102.000 INBD ØMS	76				
103.000 ØUTBD ØMS	20.0	1984.	554.	230.	2.2-99 - 100
104.000 ØUTBD ØMS	20.0	1984.	-554.	230.	
105.000 ØUTBD ØMS	40				
106.000 RIBS	6022				
107.000 TØRQUE BØX	14788				
108.000 UPR UT SKIN	222.0	1897.	73.	176.	2.2-101 - 103
109.000 UPR UT SKIN	222.0	1897.	-73.	176.	
110.000 LWR UT SKIN	253.0	1897.	73.	176.	2.2-101 - 104
111.000 LWR UT SKIN	253.0	1897.	-73.	176.	
112.000 UT SKIN	950				
113.000 UPR UT STGR	218.0	1897.	73.	176.	2.2-101 - 103
114.000 UPR UT STGR	218.0	1897.	-73.	176.	
115.000 LWR UT STGR	170.0	1897.	73.	176.	2.2-101 - 104
116.000 LWR UT STGR	170.0	1897.	-73.	176.	
117.000 UT STGR	776				
118.000 UØVER	1726				
119.000 RIB	123.0	1897.	0.	176.	2.2-101 - 105
120.000 BLØ RIB	123				
121.000 RIB	105.0	1897.	28.	176.	2.2-101 - 106
122.000 RIB	105.0	1897.	-28.	176.	
123.000 BL 23 RIB	210				

ITEM						REF PAGE
124.000	RIB	118.0	1897.	55.	176.	2.2-121
125.000	RIB	118.0	1897.	-55.	176.	
126.000	BL 55 RIB	236				
127.000	RIB	106.0	1897.	85.	176.	2.2 [illegible]
128.000	RIB	106.0	1897.	-85.	176.	
129.000	BL85 RIB	212				
130.000	RIB	114.0	1897.	119.	176.	2.2-121
131.000	RIB	114.0	1897.	-119.	176.	
132.000	BL119 RIB	228				
133.000	RIB	[illegible]				
134.000	CARRY THRU	5272				
135.000	C/C L.E.	813.0	1663.	400.	187.	2.4-5
136.000	C/CL.E.	818.0	1663.	-400.	187.	
137.000	CB L.E.	255.0	1961.	590.	237.	
138.000	CB L.E.	255.0	1961.	-590.	237.	
139.000	CB STRAKE	1563.0	1177.	180.	193.	
140.000	CB STRAKE	1563.0	1177.	-180.	193.	2.4-5
141.000	LEADING EDGE	5272				
142.000	MLG DOOR	259.0	1692.	190.	185.	2.2 [illegible]
143.000	MLG DOOR	259.0	1692.	-190.	185.	
144.000	MLG DOORS	518				
145.000	ADES DOOR	442.0	1510.	190.	185.	2.2-115
146.000	ADES DOOR	442.0	1510.	-190.	185.	
147.000	ADES DOOR	442.0	1692.	290.	185.	2.2 [illegible]
148.000	ADES DOOR	442.0	1692.	-290.	185.	
149.000	ADES DOOR	1768				
150.000	DOORS	2236				
151.000	UPR SKIN	376.0	2087.	404.	197.	2.2-2 [illegible]
152.000	UPR SKIN	376.0	2087.	-404.	197.	
153.000	LWR SKIN	372.0	2087.	404.	197.	2.2-12 [illegible]
154.000	LWR SKIN	372.0	2087.	-404.	197.	

155.000	SKIN	1496					
156.000	UPR STGR	136.0	2087.	404.	197.	2.2-112	116
157.000	UPR STGR	136.0	2087.	-404.	197.		
158.000	LWR STGR	149.0	2087.	404.	197.	2.2-112	117
159.000	LWR STGR	149.0	2087.	-404.	197.		
160.000	STGR	570					
161.000	COVER	2066					
162.000	SPAR	110.0	2024.	404.	197.	2.2-112	114
163.000	SPAR	110.0	2024.	-404.	197.		
164.000	SPARS	220					
165.000	RIBS	371.0	2059.	404.	197.	2.2-112	121
166.000	RIBS	371.0	2059.	-404.	197.		
167.000	RIBS	742					
168.000	INTERCSTL	26.0	2087.	404.	197.	2.2-112	
169.000	INTERCSTL	26.0	2087.	-404.	197.		
170.000	INTERCSTL	52					
171.000	DOORS	185.0	2020.	404.	197.	2.2-112	
172.000	DOORS	185.0	2020.	-404.	197.		
173.000	DOORS	370					
174.000	HINGES	92.0	2021.	404.	197.	2.2-112	121
175.000	HINGES	92.0	2021.	-404.	197.		
176.000	HINGES	184					
177.000	ELEVON	3634					
178.000	CONTINGENCY	2872.0	1738.	0.	194.	2.1-4	
179.000	CONTINGENCY	2872					
180.000	WING	31597					


Y100
X1425
FUSELAGE LINKS
X1600
WING CARRY THRU
X1785
X1865
X1937(REF)
X2009
X2166
ROOT RIB (RIB 1)
RIB 1
RIB 2
RIB 2A
RIB 2B
RIB 3
RIB 3A
RIB 4
RIB 4A
RIB 5
RIB 5A
RIB 5B
RIB 5C
RIB 5D
RIB 6
RIB 7
RIB 8
AUXILIARY SPAR FRONT
AUXILIARY SPAR REAR
FRONT SPAR
CENTER SPAR
REAR SPAR
ELEVON H/LINE X 2021 S REF
ELEVON
STIFFENERS AFT OF FRONT SPAR (TYP)
SKIN SUPPORTS FWD OF FRONT SPAR (TYP)
LEADING EDGE
ACCESS - ACPS VALVES
ACPS ENGINES REF
ACCESS - WIRING & PLUMBING
(REF RPT E0409 255BJ00050 REV G)
SECTION LOCATIONS
A-A THRU F-F SHEET 2
G-G THRU N-N SHEET 3
P-P THRU W-W SHEET 4
Y-Y SHEET 3
NOTE -
LAST SECTION LETTER USED - AH
REVISIONS
ZONE | LTR | DESCRIPTION | DATE | APPROVED
MCDONNELL DOUGLAS
ST LOUIS
WING STRUCTURAL ASSY
DELTA WING ORBITER
CODE IDENT NO. 76301
255BJ11138
SIZE E
SCALE 1/20
WT
LB
SHEET 1 OF 4



SECURITY CLASS	DRAWING NUMBER	REV	SH
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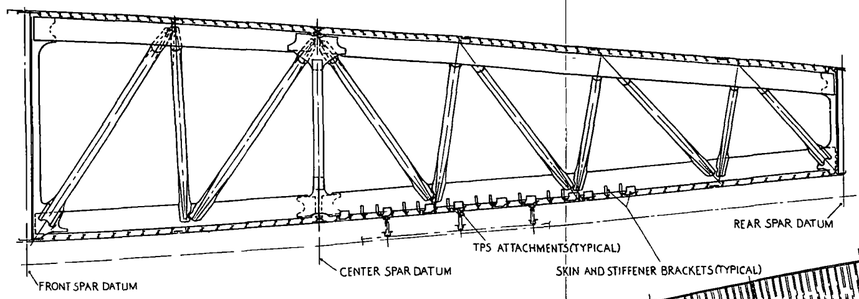
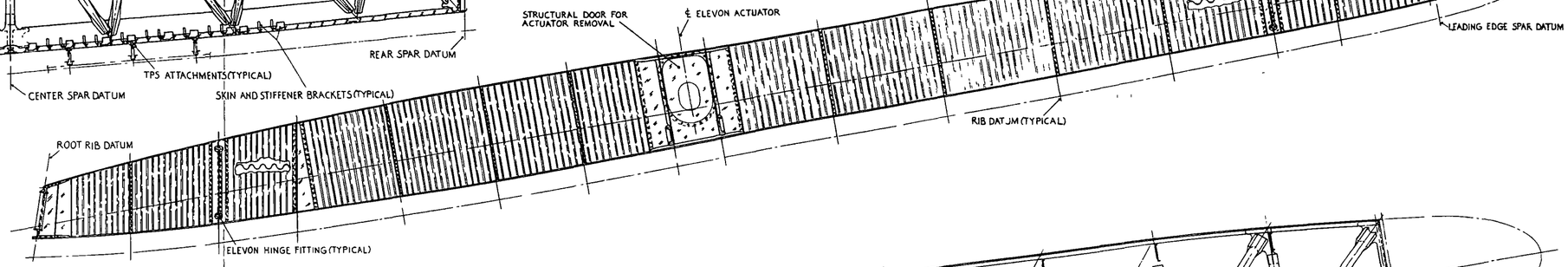
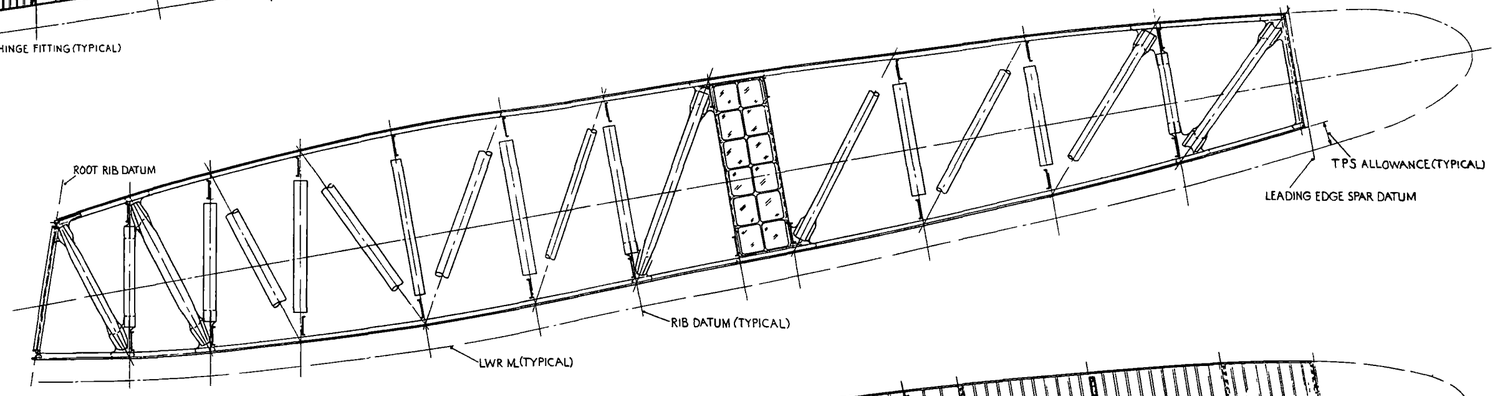


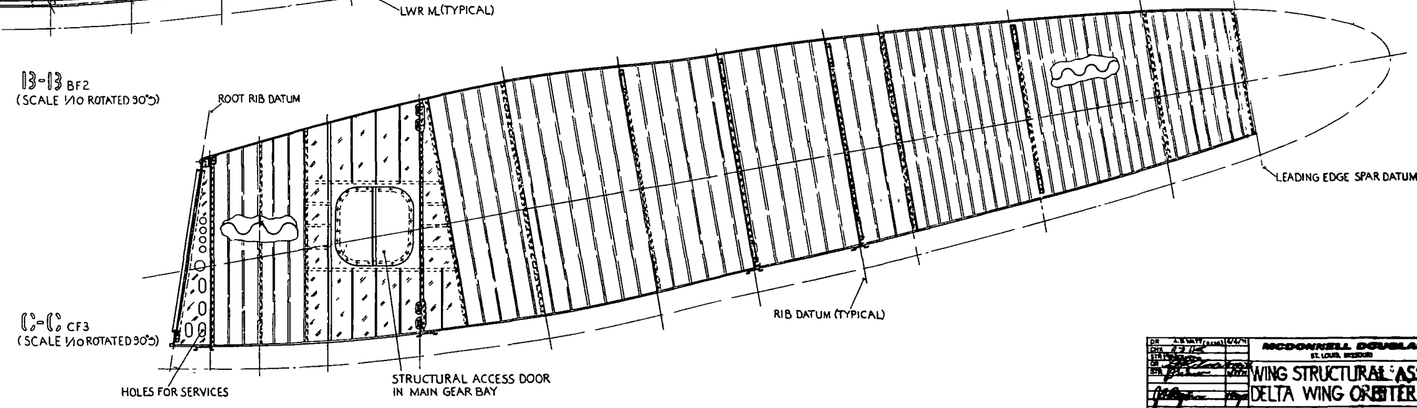
E2
(SCALE 1/10)
TYPICAL RIB



A-A BF2
(SCALE 1/10 ROTATED 30°)



B-B BF2
(SCALE 1/10 ROTATED 30°)



C-C CF3
(SCALE 1/10 ROTATED 30°)

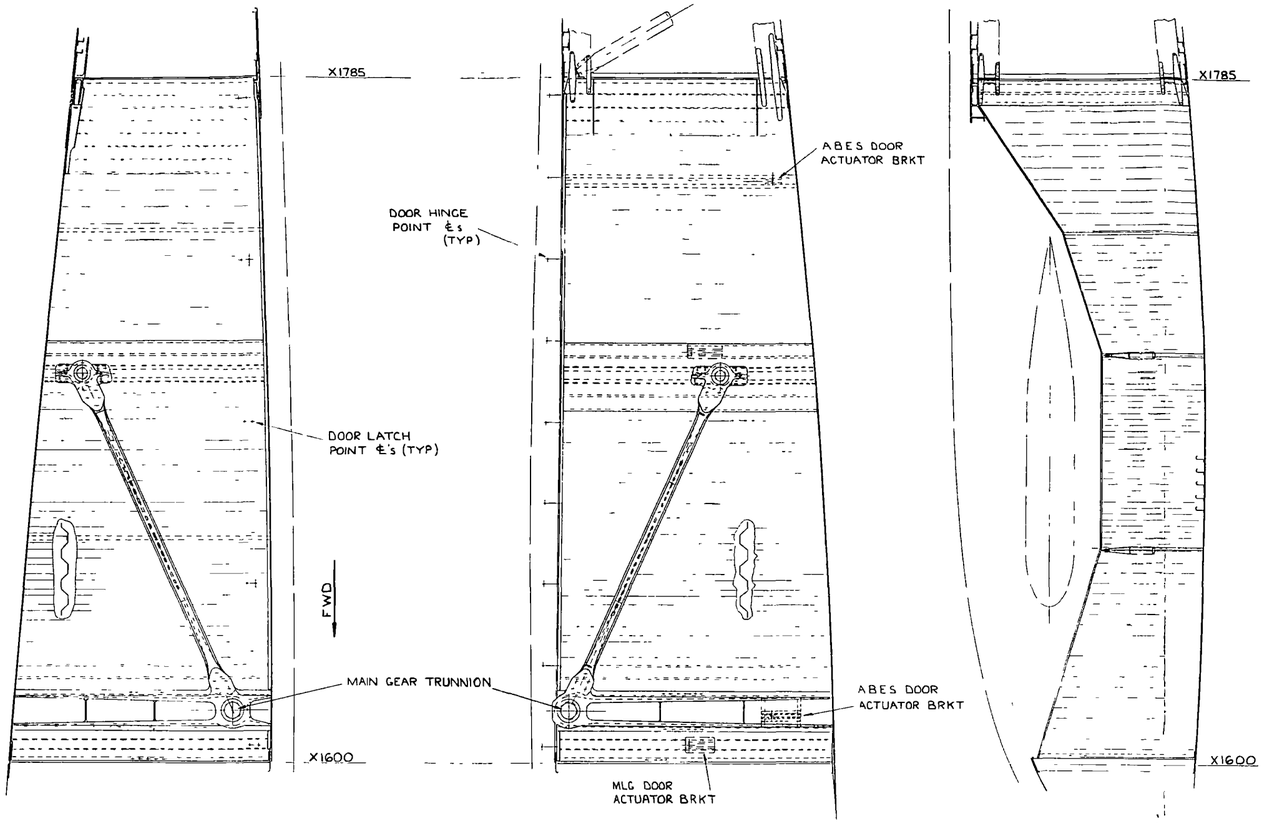
REVISIONS			
ZONE	LTR	DESCRIPTION	DATE

DR	A.S.WHITE	6/4/71
CHK		
APPD		
APPD		
APPD		

McDONNELL DOUGLAS
ST. LOUIS, MISSOURI

WING STRUCTURAL ASSY.
DELTA WING ORBITER

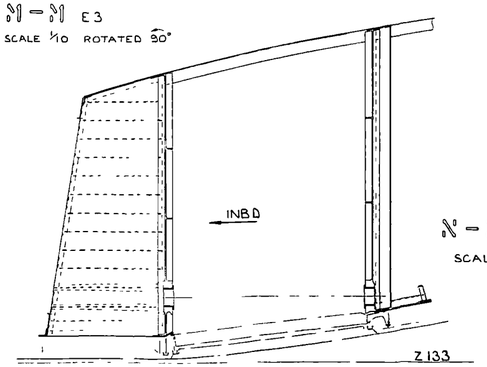
SIZE: D | CODE IDENT NO. 80205 | 255BJ11138



M – M E3
SCALE 1/10 ROTATED 90°

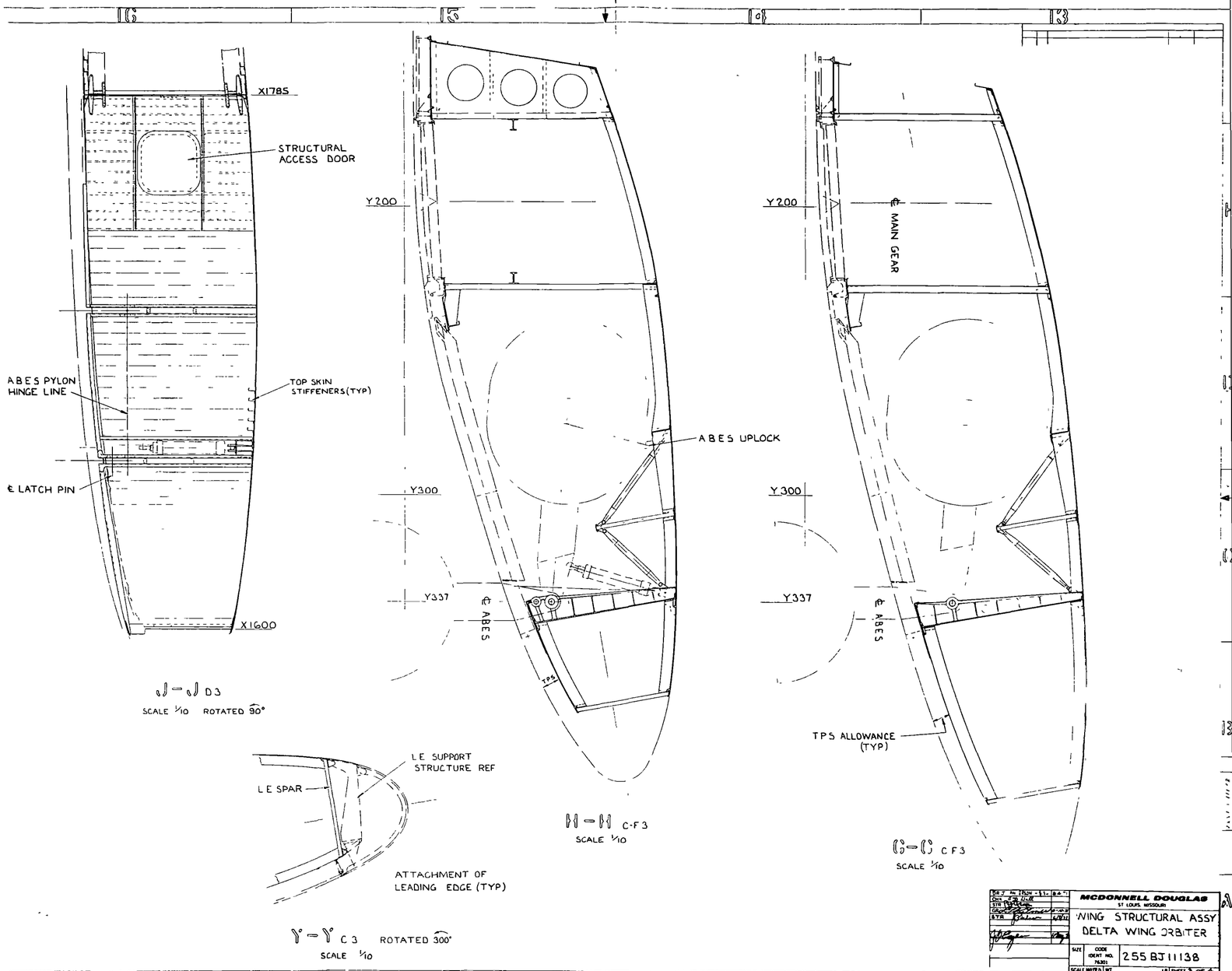
L – L E3
SCALE 1/10 ROTATED 90°

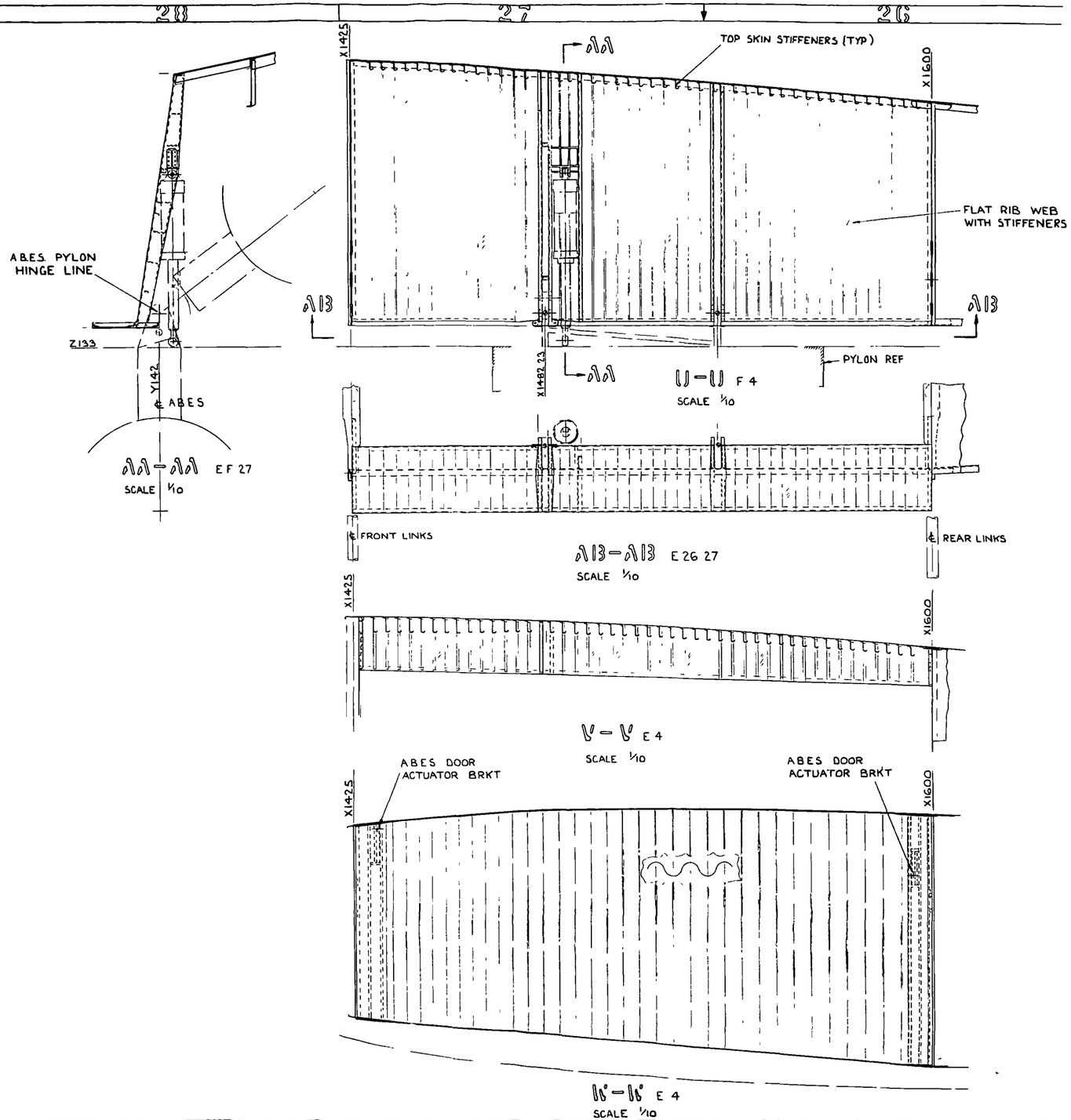
K – K E3
SCALE 1/10 ROTATED 90°



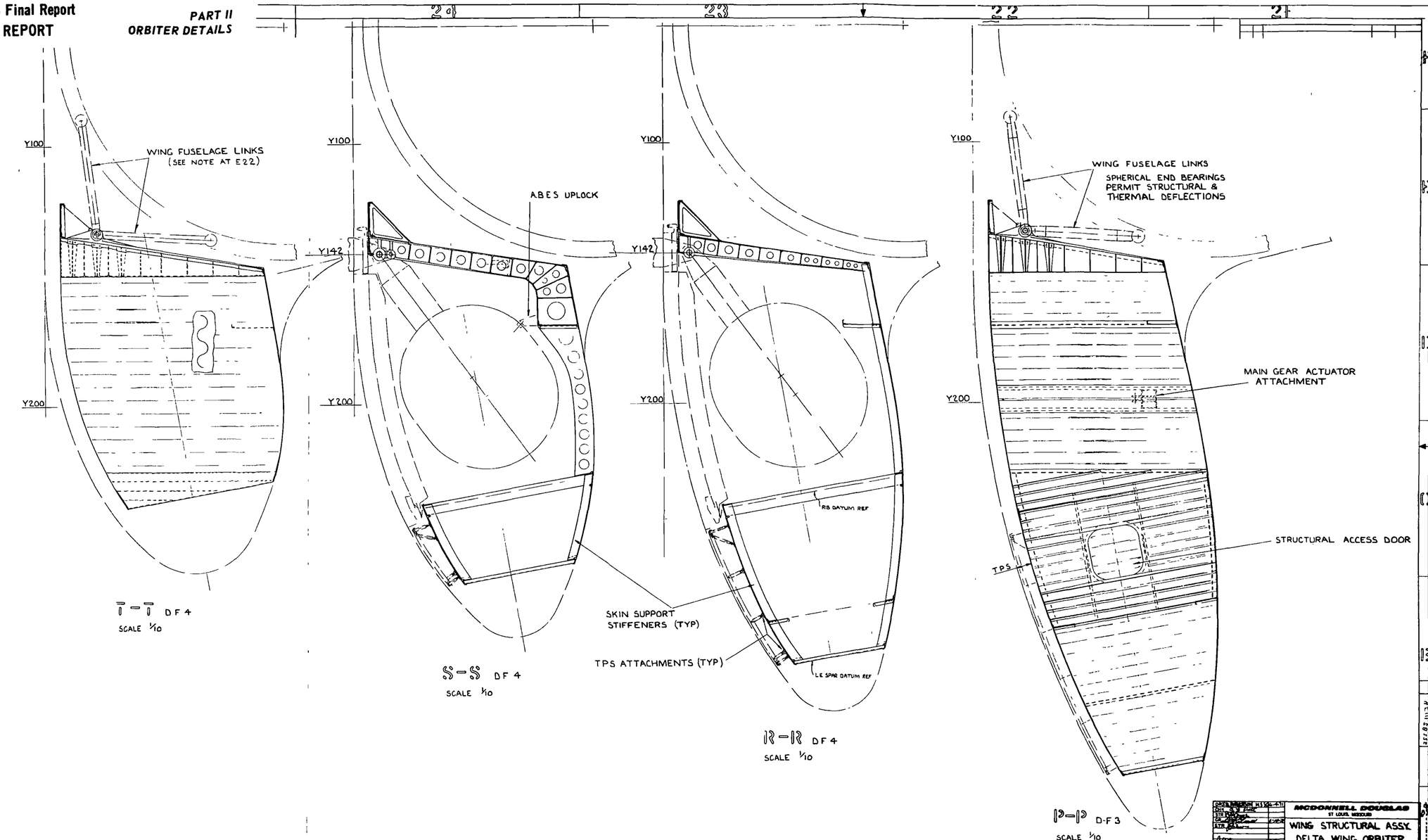
N – N E F 3
SCALE 1/10 ROTATED 90°

DRAWING NUMBER 255 BJ 11138 REV LET 3

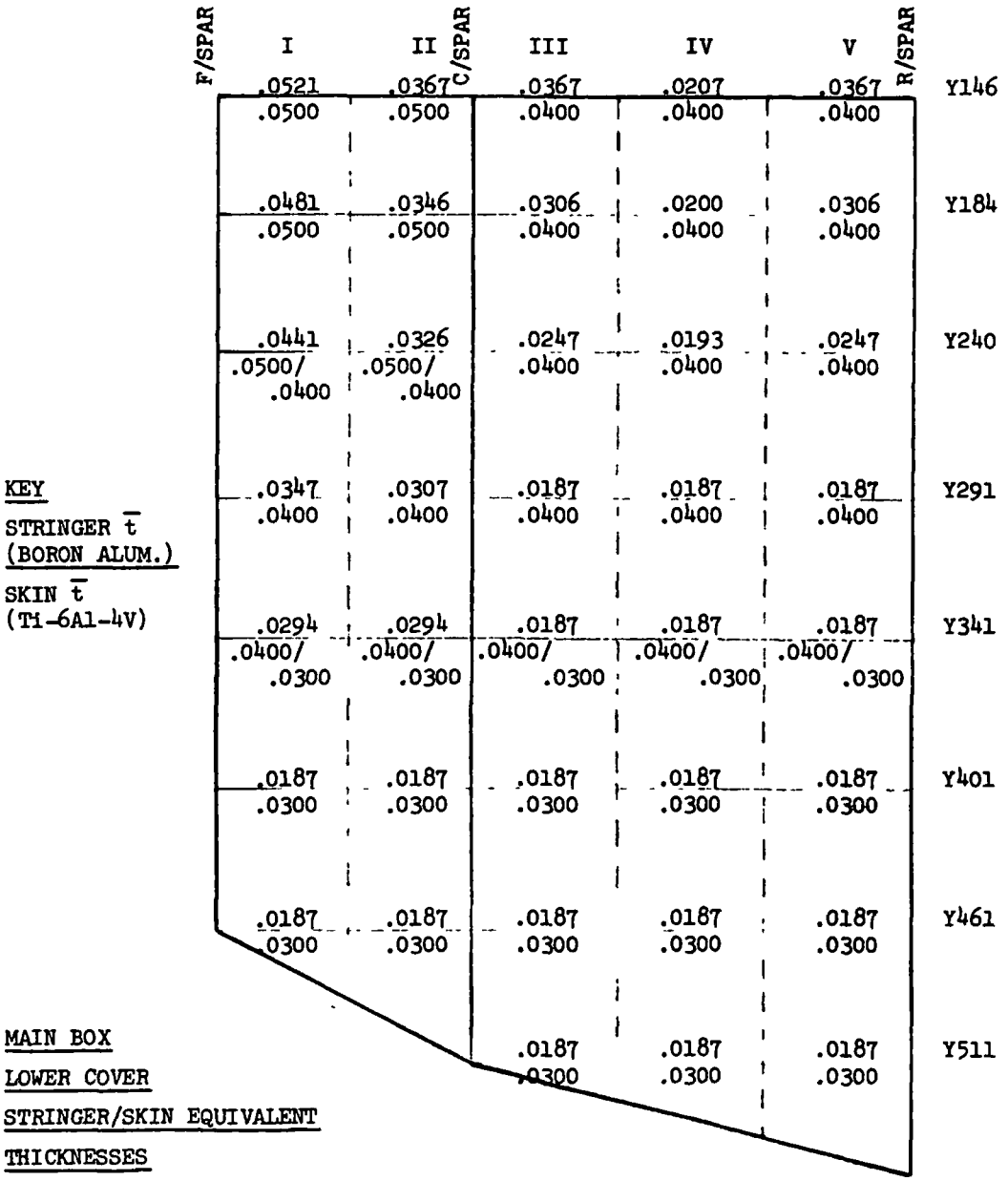

X1785
STRUCTURAL ACCESS DOOR
ABES PYLON HINGE LINE
TOP SKIN STIFFENERS(TYP)
℄ LATCH PIN
X1600
J – J D3
SCALE 1/10 ROTATED 90°
Y200
Y300
Y337
℄ ABES
TPS
ABES UPLOCK
H – H C-F3
SCALE 1/10
Y200
℄ MAIN GEAR
Y300
Y337
℄ ABES
TPS ALLOWANCE (TYP)
G – G C F3
SCALE 1/10
L.E SUPPORT STRUCTURE REF
L.E SPAR
ATTACHMENT OF LEADING EDGE (TYP)
F – F C 3 ROTATED 300°
SCALE 1/10
MCDONNELL DOUGLAS
ST LOUIS, MISSOURI
WING STRUCTURAL ASSY
DELTA WING ORBITER
SIZE
CODE IDENT NO. 76301
255 BJ 11138
SCALE NOTED
WT
LB SHEET 3 OF 4



DRAWING NUMBER	REV	SH.
255 BJ 11138		4


Y100
WING FUSELAGE LINKS
(SEE NOTE AT E22)
Y200
T – T DF 4
SCALE 1/10
Y100
ABES UPLOCK
Y142
Y200
S – S DF 4
SCALE 1/10
Y100
Y142
Y200
SKIN SUPPORT
STIFFENERS (TYP)
TPS ATTACHMENTS (TYP)
RIB DATUM REF
LE SPAR DATUM REF
R – R DF 4
SCALE 1/10
Y100
WING FUSELAGE LINKS
SPHERICAL END BEARINGS
PERMIT STRUCTURAL &
THERMAL DEFLECTIONS
Y200
MAIN GEAR ACTUATOR
ATTACHMENT
STRUCTURAL ACCESS DOOR
OML
TPS
P – P D-F 3
SCALE 1/10

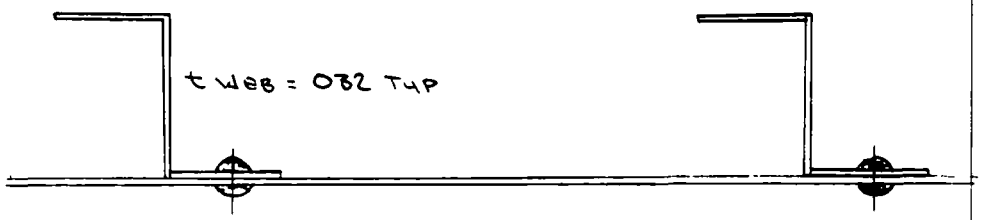
MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER



5-3-71	J GARRISON	WING	LOWER TORQUE BOX	1/12

TORQUE BOX LOWER SURFACE
FS 1785 TO 2009

W_F = 0.7 TYP NOTE. ALL ROUND HEAD FASTENERS ON LWR SURFACE



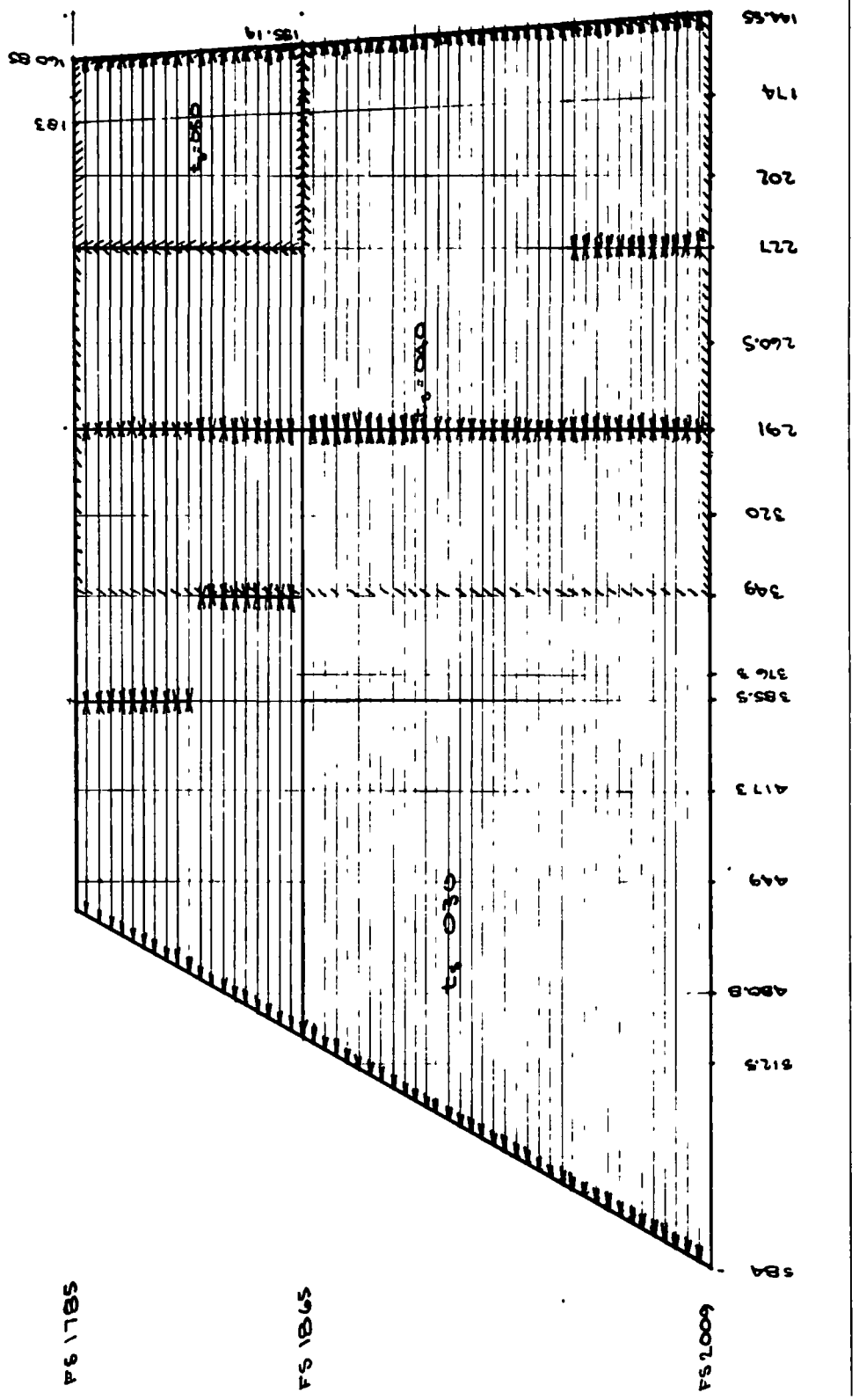
PITCH = 4 IN TYP

BORON - ALUMINUM STRINGERS ρ = .095 PCI
FLANGE t VARIES IN 008 INCREMENTS
STRINGER H = 1.0 IN OUTB'D OF RIB #4
" " TAPERS FROM 1.0 IN TO 1.25 IN INB'D OF RIB # 4
6Al 4V TITANIUM COVER MAT'L ρ = .164 PCI

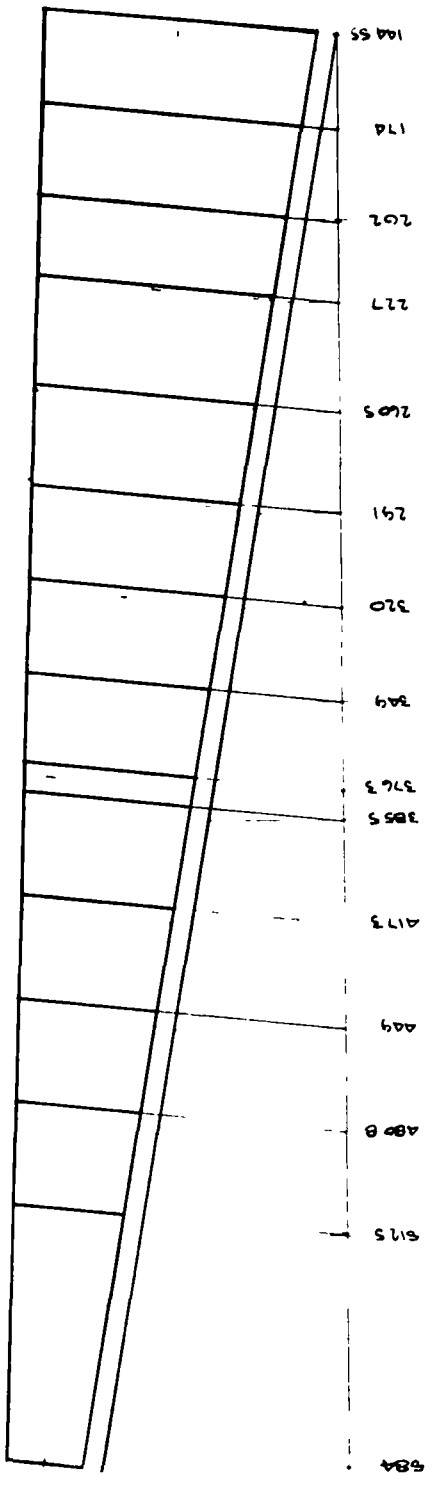
5/32 Ti RIVETS ON 4D CTRS = .625 PITCH

UNIT WT = 00102 + 00072 = 00174 (HL 10 + HL 70)

5-4-71	J GARRISON	WING	LOWER TORQUE BOX	2/12



5-3-71	J GARRISON	WING	TORQUE BOX



5-4-71	J GARRISON	WING	LOWER TORQUE BOX	3/12

AREA CORRECTION = $\frac{1}{.9848}$ = 1.0154

050 PANEL

$S = (71.86 + 66.15)\frac{1}{2} * 1.0154 * 80 = 5605.4$ in²

IDEAL WT = 5605.4 * 050 * .164 = 45.96 ⌐ 46LB

040 PANEL

$S = (193.86 + 200.85)\frac{1}{2} * 1.0154 * 144 = 29120$
$122 * 1.0154 * 80 = 9910$
39030 in²

IDEAL WT = 39030 * 040 * .164 = 256 LB

030 PANEL

$S = (125 + 285)\frac{1}{2} * 1.0154 * 224 = 40941$ in²

IDEAL WT = 40941 * 030 * .164 = 201 LB

TOTAL IDEAL LWR T/B COVER WT = 503 LB

5-4-71	J GARRISON	WING	LWR TORQUE BOX	9/12

STRINGERS ON CONSTANT 4 IN PITCH

FOR BORON-ALUMINUM, THICKNESS VARIES WITH RESPECT TO THE QUANTITY OF LAMINATES WITH .008 IN/PLY.

BASIC X-SEC AREAS

h = 1 IN .032 tf	S = .077 IN^2
h = 1 IN .040 tf	S = .088 IN^2
h = 1 IN .048 tf	S = .099 IN^2
h = 1 IN .056 tf	S = .110 IN^2
h = 1 IN .064 tf	S = .122 IN^2
h = 1 IN .072 tf	S = .133 IN^2
h = 1 IN .080 tf	S = .144 IN^2
h = 1 IN .088 tf	S = .155 IN^2
h = 1 IN .096 tf	S = .167 IN^2
h = 1.25 IN .032 tf	S = .085 IN^2
h = 1.25 IN .040 tf	S = .096 IN^2
h = 1.25 IN .048 tf	S = .107 IN^2
h = 1.25 IN .056 tf	S = .118 IN^2
h = 1.25 IN .064 tf	S = .130 IN^2
h = 1.25 IN .072 tf	S = .141 IN^2
h = 1.25 IN .080 tf	S = .152 IN^2
h = 1.25 IN .088 tf	S = .163 IN^2
h = 1.25 IN .096 tf	S = .174 IN^2

1789 STG'R

90"	CONSTANT	90 x .077	= 6.93	in³
96"	TAPER	96(.077 + .167)½	= 11.7	in³
130"	TAPER	130 x(.167 +.174)½	= 22.2	
		Σ	= 40.83	

Wt = 40.83 x 1.0154 x .095 = 3.94 LB

1793 STG'R

92"	CONSTANT	92 x .077	= 7.08	
96'	TAPER	96(.077+.167)½	= 11.7	
130	TAPER	130 x(.167 +.174)½	= 22.2	
			40.98	

Wt = 40.98 x 1.0154 x .095 = 3.95 LB

1797 STG'R

94"	CST	94 x .077	= 7.25	
96"	TPR	96(.077+.167)½	= 11.7	
130"	TPR	130 x(.167 +.174)½	= 22.2	
			41.15	

Wt = 41.15 x 1.0154 x .095 = 3.97 LB

1801 STG'R

97"	CST	97 x .077	= 7.47	
96'	TPR	96(.077+.167)½	= 11.7	
131"	TPR	131 x(.167 +.174)½	= 22.2	
			41.37	

Wt = 41.37 x 1.0154 x .095 = 3.99 LB

1805 STG'R

98"	CST	98 x .077	= 7.55	
96"	TPR	96(.077+.167)½	= 11.7	
131"	TPR	131 (.167+.174)½	= 22.2	
			41.45	

Wt 41.45 x 1.0154 x .095 = 4.00 LB

1809 STG'R

100	CST	100 x .077	= 7.70	
96	TPR	96(.077+.167)½	= 11.70	
131	TPR	131 (.167+.174)½	= 22.2	
			41.60	

Wt 41.6 x 1.0154 x .095 = 4.01 LB

1813 STG'R

102	CST	102 x .077	= 7.85	
96	TPR	96(.077+.167)½	= 11.70	
131	TPR	131 (.167+.174)½	= 22.2	
			41.75	

Wt 41.75 x 1.0154 x .095 = 4.03 LB

27.89

1817 STG'R

104 CST	104 × .077	=	8.01	
96 TPR	96(.077+.167)½	=	11.7	
132 TPR	132(.167+.174)½	=	22.51	
			42.22	
WT	42.22 × .0965			= 4.07

1821 STG'R

106 CST	106 × .077	=	8.16	
96 TPR	96(.077+.167)½	=	11.7	
132 TPR	132(.167+.174)½	=	22.51	
			42.37	
WT	42.37 × .0965			= 4.09

1825 STG'R

108 CST	108 × .077	=	8.32	
96 TPR	96(.077+.167)½	=	11.7	
132 TPR	132(.167+.174)½	=	22.51	
			42.53	
WT	42.53 × .0965			= 4.10

1829 STG'R

CST	147 × .077	=	11.32	
TPR	59 (.077+.088)½	=	4.87	
TPR	132 (.088+.130)½	=	14.39	
			30.58	
WT	30.58 × .0965			= 2.95

1833 STG'R

CST	148 × .077	=	11.40	
TPR	59 (.077+.088)½	=	4.87	
TPR	132 (.088+.130)½	=	14.39	
			30.66	
WT	30.66 × .0965			= 2.96

1837 STG'R

CST	150 × .077	=	11.55	
TPR	59 (.077+.088)½	=	4.87	
TPR	132 (.088+.130)½	=	14.39	
			30.81	
WT	30.81 × .0965			= 2.97

1841 STG'R

CST	152 × .077	=	11.70	
TPR	59 (.077+.088)½	=	4.87	
TPR	133 (.088+.130)½	=	14.50	
			31.07	
WT	31.07 × .0965			= 3.00

24.17

1845 STG'R

CST	184	x.077	= 11.86	
TPR	59	(.077+.088)½	= 4.87	
TPR	133	(.088+.130)½	= 14.50	
			31.23	
WT	31.23 x .0965			= 3.01 LB

1849 STG'R

CST	156	x.077	= 12.01	
TPR	59	(.077+.088)½	= 4.87	
TPR	133	(.088+.130)½	= 14.50	
			31.38	
WT	31.30 x .0965			= 3.03

1853 STG'R

CST	158	x.077	= 12.12	
TPR	59	(.077+.088)½	= 4.87	
TPR	134	(.088+.130)½	= 14.61	
			31.60	
WT	31.60 x .0965			= 3.05

1857 STG'R

CST	160	x.077	= 12.32	
TPR	59	(.077+.088)½	= 4.87	
TPR	134	(.088+.130)½	= 14.61	
			31.80	
WT	31.80 x .0965			= 3.07

1861 STG'R

CST	162	x.077	= 12.47	
TPR	59	(.077+.088)½	= 4.87	
TPR	134	(.088+.130)½	= 14.61	
			31.95	
WT	31.95 x .0965			= 3.08

1869 STG'R

CST	225	x.077	= 17.32	
TPR	135	(.077+.130)½	= 13.97	
			31.29	
WT	31.29 x .0965			= 3.02

1873 STG'R

CST	227	x.077	= 17.48	
TPR	135	(.077+.130)½	= 13.97	
			31.44	
WT	31.44 x .0965			= 3.03

21 29

1877	STG'R			
	CST	228 x077	= 1756	
	TPR	135 $(077+130)\frac{1}{2}$	= 1397	
			31.53	
	WT	31 53 x .0965		= 3.04 LB
1881	STG'R	230 x077	= 1771	
	CST	136 $(077+130)\frac{1}{2}$	= 1408	
	TPR		31 79	
	WT	31 79 x 0965		= 3.07
1885	STG'R			
	CST	232 x077	= 1786	
	TPR	136 $(077+130)\frac{1}{2}$	= 1408	
			31 94	
	WT	31 94 x 0965		= 3 08
1889	STG'R			
	CST	234 x077	= 1802	
	TPR	136 $(077+130)\frac{1}{2}$	= 1408	
			32.10	
	WT	32.10 x 0965		= 3 10
1893	STG'R			
	CST	236 x077	= 1817	
	TPR	137 $(077+130)\frac{1}{2}$	= 1418	
			32 35	
	WT	32 35 x 0965		= 3 12
1897	STG'R			
	CST	238 x077	= 1833	
	TPR	137 $(077+130)\frac{1}{2}$	= 1418	
			32 51	
	WT	32.51 x 0965		= 3 14
1901	STG'R			
	CST	240 x077	= 1848	
	TPR	137 $(077+130)\frac{1}{2}$	= 1418	
			32 66	
	WT	32 66 x 0965		= 3 15
1905	STG'R			
	CST	242 x077	= 1863	
	TPR	138 $(077+130)\frac{1}{2}$	= 1428	
			32 91	
	WT	32 91 x 0965		= 3.17

29.87

1909 STG'R

CST	244 × 077	=	18 79
TPR	188 (077+.130)½	=	14.28
			33.07
WT	33 07 × 0965		= 3 19

1913 STG'R

CST	246 × 077	=	18 94
TPR	139 (077+085)½	=	11.26
			30 20
WT	30.20 × 0965		= 2.91

1917 STG'R

CST	248 × 077	=	19 10
TPR	139 (077+085)½	=	11 26
			30 36
WT	30 36 × 0965		= 2.93

1923 STG'R

CST	250 × 077	=	19 29
TPR	139 (077+085)½	=	11 26
			30.51
WT	30.51 × 0965		= 2.94

1927 STG'R

CST	252 × 077	=	19 40
TPR	100 (077+085)½	=	11.34
			30.74
WT	30 74 × 0965		= 2.96

1931 STG'R

CST	254 × 077	=	19 56
TPR	100 (077+085)½	=	11 34
			30.90
WT	30 90 × 0965		= 2 98

1934 STG'R

CST	256 × 077	=	19 71
TPR	100 (077+085)½	=	11 34
			31.05
WT	31.05 × 0965		= 3 00

1937 STG'R

CST	258 × 077	=	19.87
TPR	101 (077+085)½	=	11.42
			31.29
WT	31 29 × 0965		= 3.02

2393

10/12

1941	STG'R			
	CST	260 x 077	= 2002	
	TPR	141 (077+085) ½	= 11 42	
			31 44	
	WT	31.44 x 0965		= 303
1945	STG'R			
	CST	262 x 077	= 2017	
	TPR	141 (077+085) ½	= 11 42	
			31 59	
	WT	31 59 x 0965		= 3 05
1949	STG'R			
	CST	264 x 077	= 2033	
	TPR	142 (077+085) ½	= 11 50	
			31 83	
	WT	31 83 x 0965		= 3 07
1953	STG'R			
	CST	266 x 077	= 20.48	
	TPR	142 (077+085) ½	= 11 50	
			31 98	
	WT	31 98 x 0965		= 3 08
1957	STG'R			
	CST	268 x 077	= 2064	
	TPR	142 (077+085) ½	= 11 50	
			32.14	
	WT	32.14 x 0965		= 3 10
1961	STG'R			
	CST	270 x 077	= 20.79	
	TPR	64 (077 +081) ½	= 5 06	
	TPR	79 (081 + .130) ½	= 8 33	
			34.18	
	WT	34.18 x 0965		= 3 30
1965	STG'R			
	CST	272 x 077	= 2094	
	TPR	64 (077+081) ½	= 5 06	
	TPR	79 (081 + .130) ½	= 8 33	
			34 33	
	WT	34 33 x 0965		= 3 31

21.94

1969 STG'R

CST	274 x 077	=	21.10
TPR	64 (077+081) ½	=	5.06
TPR	79 (081+130) ½	=	8.33
			34.49
Wt	34 49 x 0965		= 3.33

1973 STG'R

CST	276 x 077	=	21 25
TPR	64 (077+081) ½	=	5 06
TPR	80 (081+.130) ½	=	8.44
			34 75
Wt	34 75 x 0965		= 3 35

1977 STG'R

CST	278 x 077	=	21.41
TPR	64 (077+081) ½	=	5 06
TPR	80 (081+130) ½	=	8.44
			34 91
Wt	34 91 x 0965		= 3 37

1981 STG'R

CST	280 x 077	=	21 56
TPR	64 (077+081) ½	=	5 06
TPR	80 (081+130) ½	=	8.44
			35 06
Wt	35 06 x 0965		= 3 38

1985 STG'R

CST	282 x 077	=	21.71
TPR	64 (077+081) ½	=	5 06
TPR	81 (081+130) ½	=	8 55
			35 32
Wt	35 32 x 0965		= 3 41

1989 STG'R

CST	284 x 077	=	21 87
TPR	64 (077+081) ½	=	5.06
TPR	81 (081+130) ½	=	8.55
			35 48
Wt	35 48 x 0965		= 3 42

1991 STG'R

CST	286 x 077	=	22 02
TPR	64 (077+081) ½	=	5 06
TPR	82 (081+.130) ½	=	8.65
			35 73
Wt	35.73 x 0965		= 3.45

23.71

12/12

2005 STG'R

CST	288	x077	= 22.18
TPR	69	(077+081)½	= 5 06
TPR	82	(081+130)½	= 8 65
			35 89
WT	35 89 x 0965		= 3 46

TOTAL IDEAL STRINGERS 1711 26 LB

TOTAL IDEAL COVER 503 LB

TOTAL SKIN & STG'R 674 LB

RIVETS $\frac{85576}{4 \times 625}$ x 00174 = 60 LB

NON OPTIMISM IS TAKEN AS FASTENERS PLUS MATERIAL TOLERANCE

60 LB OF FASTENERS ↳ 10%
GAGE TOL ↳ 5%

USE 15%

SKIN 1.15 * 503 = 579 LB 8.000

STG'R 1.15 * 171 = 196 LB 17 000

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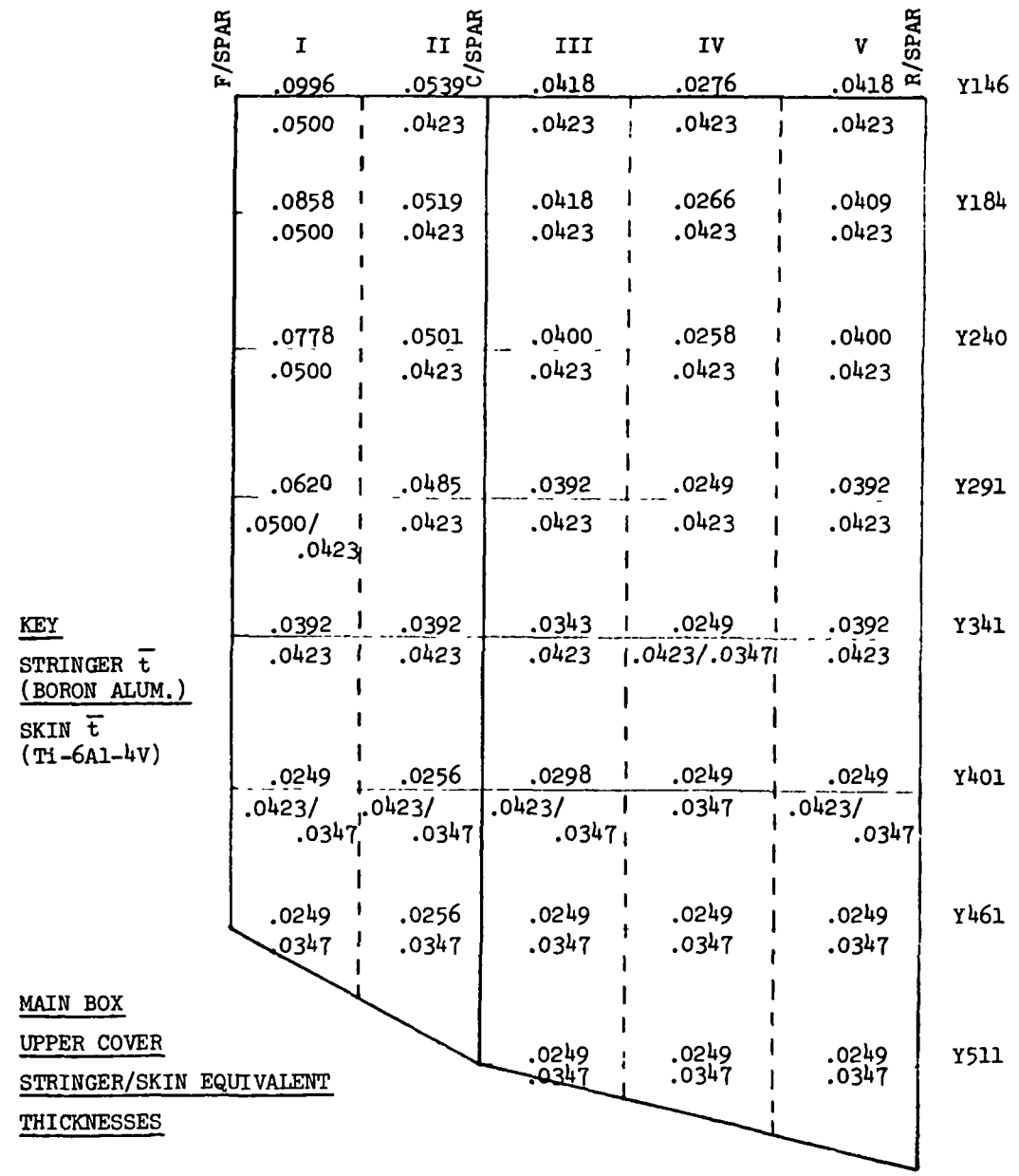
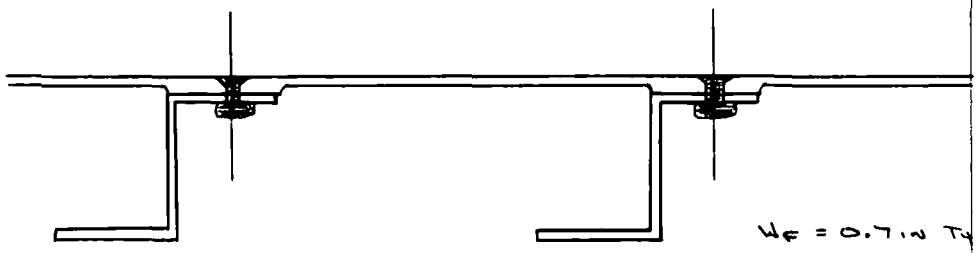


5-6-71	J GARRISON	WING	UPPER TORQUE BOX	1/15

TORQUE BOX UPPER SURFACE
FS 1785 TO 2009



PITCH = 3 INCH TYPICAL

BORON-ALUMINUM STRINGERS ρ = .095 PCI
FLANGE & WEB THICKNESS VARIES IN 008 INCREMENTS
STRINGER HEIGHT - 1.0 IN CONSTANT OUTBOARD OF RIB No 4
STRINGER HEIGHT TAPERS TO 1.5 IN IN BAY 1
STRINGER HEIGHT TAPERS TO 1.25 IN IN REMAINING BAYS

6-6-2 TITANIUM COVER MAT'L ρ = 164 PCI

050 MIN THICKNESS FOR COUNTERSUNK RIVETS
AREA CORRECTION FOR PADS

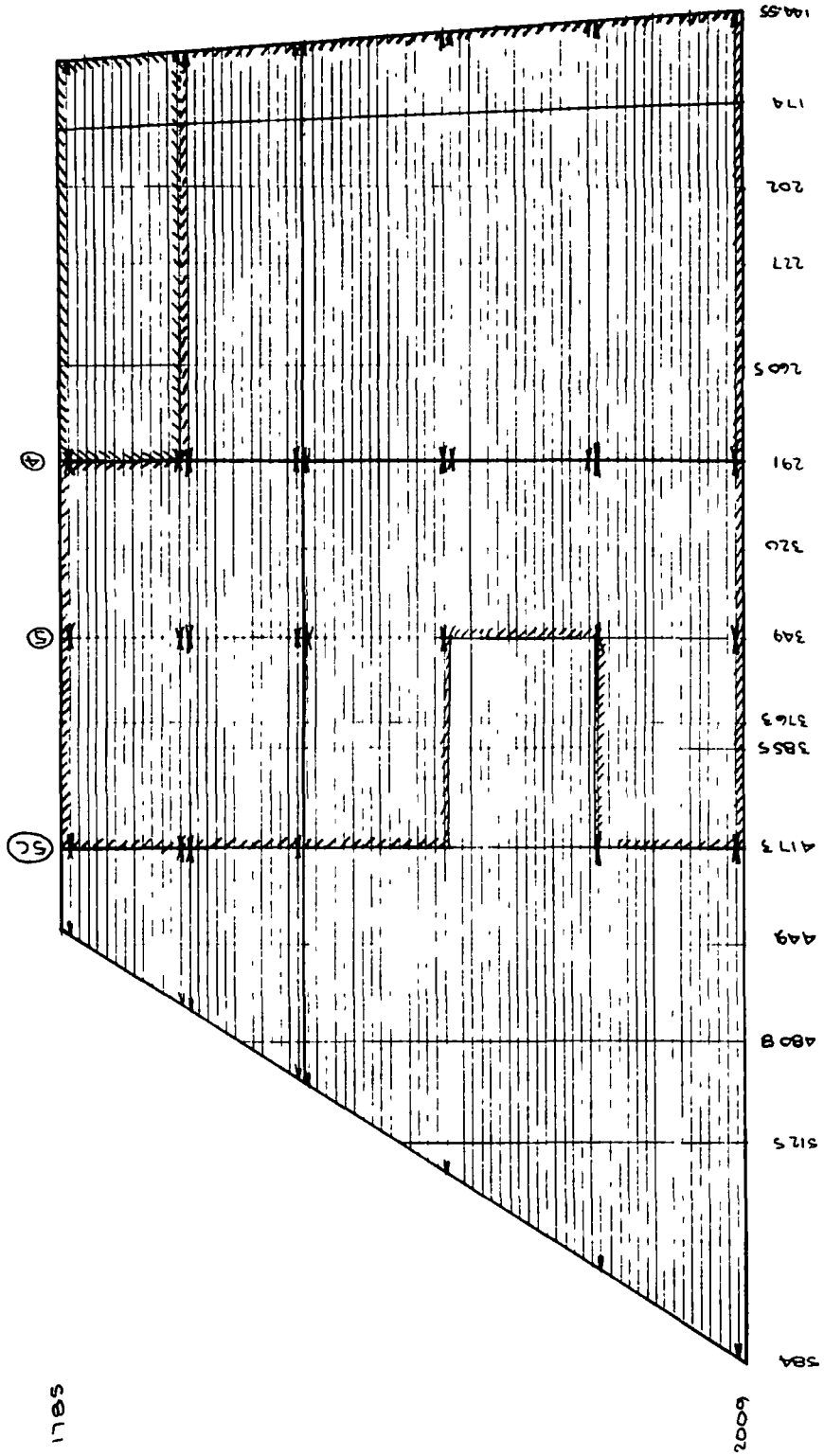
040 BASIC SKIN
$(3 \times 040 + .7 \times 010) \frac{1}{3} = .0423$

030 BASIC SKIN
$(3 \times 030 + .7 \times 020) \frac{1}{3} = .0347$

5/32 Ti COUNTERSUNK RIVETS ON .40 CTRS = .625 PITCH

UNIT WT = .00072 (HL 11 + HL 70)

5-6-71	J GARRISON	WING	UPPER TORQUE BOX	2/15



5-6-71	J GARRISON	WING	UPPER TORQUE BOX	3/15

AREA CORRECTION = $\frac{1}{.9848}$ = 1.0154

050 PANEL

$S = (130 + 133)\frac{1}{2} \times 40 \times 1.0154 = 5340\ IN^2$

IDEAL WT = 5340 × 050 × .164 = 436 LB

040 PANEL

$S = (277.75 + 256.45)\frac{1}{2} \times 224 \times 1.0154$ = 60000

LESS 050 = -5340

LESS 030 683.44 × 1.0154 = -3051

51609 IN^2

IDEAL WT = 50717 × 0423 × .164 = 352 LB

030 PANEL

$S = (58 + 167)\frac{1}{2} \times 224 \times 1.0154$ = 25600

SEGMENT +3051

28651 IN^2

IDEAL WT = 28651 × 0347 × 164 = 163 LB

TOTAL IDEAL UPR T/B COVER WT = 559 LB

5-6-71	J GARRISON	WING	UPR TORQUE BOX	4/15

STRINGERS ON CONSTANT 3 IN PITCH

PANEL 1

h=1,	T_F = 032,	T_W = 032	S= 077 IN^2
h=1,	T_F = 064,	T_W 032	S = .122 IN^2
h=1,	T_F = 064	T_W = 064	S = .154 IN^2
h=1,	T_F = 096	T_W = 064	S = .199 IN^2
h=1.5	T_F = .128	T_W = 096	S = .273 IN^2

PANEL 2

h= 1	T_F = 032	T_W = 032	S = 077 IN^2
h. 1	T_F = 064	T_W = 032	S = .122 IN^2
h= 1	T_F = 064	T_W = 064	S = .154 IN^2
h. 125	T_F = 064	T_W = 064	S = .170 IN^2

PANEL 3

h= 1	T_F = 032	T_W = 032	S = 077 IN^2
h= 1	T_F = 064	T_W = 032	S = .122 IN^2
h= 1.25	T_F = 064	T_W = 032	S = .130 IN^2

PANEL 4

h= 1	T_F = 032	T_W = 032	S = 077 IN^2
h= 1.25	T_F = 032	T_W = 032	S = 085 IN^2

PANEL 5

h= 1	T_F = 032	T_W = 032	S = 077 IN^2
h= 1	T_F = 064	T_W = 032	S = .122 IN^2
h= 1.25	T_F = 064	T_W = 032	S = .130 IN^2

5-6-71	J GARRISON	WING	UPR TORQUE BOX	5/15

BAY #1

1788 STG'R

59 × .077 = 4.54
69 (.077 + .122)½ = 6.87
58 (.122 + .199)½ = 9.31
130 (.199 + .273)½ = 30.68
51.40 × 1.0154 × .095 = 4.96 LB

1791 STG'R

61 × .077 = 4.70
69 (.077 + .122)½ = 6.87
58 (.122 + .199)½ = 9.31
130 (.199 + .273)½ = 30.68
51.56 × 1.0154 × .095 = 4.97 LB

1794 STG'R

63 × .077 = 4.85
69 (.077 + .122)½ = 6.87
58 (.122 + .199)½ = 9.31
130 (.199 + .273)½ = 30.68
51.71 × 1.0154 × .095 = 4.99 LB

1797 STG'R

64 × .077 = 4.93
69 × (.077 + .122)½ = 6.87
58 (.122 + .199)½ = 9.31
130 (.199 + .273)½ = 30.68
51.79 × 1.0154 × .095 = 5.00 LB

1800 STG'R

66 × .077 = 5.08
69 (.077 + .122)½ = 6.87
58 (.122 + .199)½ = 9.31
131 (.199 + .273)½ = 30.92
52.18 × 1.0154 × .095 = 5.03 LB

1803 STG'R

67 × .077 = 5.16
69 (.077 + .122)½ = 6.87
58 (.122 + .199)½ = 9.31
131 (.199 + .273)½ = 30.92
52.26 × 1.0154 × .095 = 5.04 LB

6/15

1806 STG'R

68 x 077 = 5.24
69(077 + 122) ½ = 6 87
58(122 + 199) ½ = 9.31
131 (199 + 273) ½ = 30.92
52 39 x 1.0154 x 095 = 505 LB

1809 STG'R

69 (077) = 5 31
69 (077 + 122) ½ = 6 87
58 (122 + 199) ½ = 9 31
131 (199 + 273) ½ = 30 92
52 41 x 1 0154 x 095 = 506 LB

1812 STG'R

71 x 077 = 5 47
69(077 + 122) ½ = 6.87
58(122 + 199) ½ = 9 31
132(199 + 273) ½ = 31.15
53.16 x 1 0154 x 095 = 5 13 LB

1815 STG'R

73 x 077 = 5.62
69(077 + 122) ½ = 6 87
58(122 + 199) ½ = 9 31
132(199 + 273) ½ = 31 15
53 31 x 1 0154 x 095 = 5.14 LB

1818 STG'R

74 x 077 = 5.70
69(077 + 122) ½ = 6.87
58(122 + 199) ½ = 9 31
132(199 + 273) ½ = 31.15
53 39 x 1 0154 x 095 = 5 15 LB

1821 STG'R

75 x 077 = 5 78
69(077 + 122) ½ = 6 87
58(122 + 199) ½ = 9 31
133(199 + 273) ½ = 31.39
53 35 x 1 0154 x 095 = 5.15 LB

1824 STG'R

77 x 077 = 5 93
69 (077 + 122) ½ = 6 87
58 (122 + 199) ½ = 9 31
133 (199 + 273) ½ = 31 39
53.50 x 1 0154 x 095 = 5.16 LB

65.83

7/15

BAY 2

STG'R 1827

79 × .077	= 6.08	
69 (.077+.122)½	= 6.87	
58 (.122+.154)½	= 8.00	
133 (.154+.170)½	= 21.55	
	42.50	× 1.0154 × .095 = 4.10 LB

STG'R 1830

80 × .077	= 6.16	
69 (.077+.122)½	= 6.87	
58 (.122+.154)½	= 8.00	
133 (.154+.170)½	= 21.55	
	42.59	× 1.0154 × .095 = 4.11 LB

STG'R 1833

82 × .077	= 6.31	
69 (.077+.122)½	= 6.87	
58 (.122+.154)½	= 8.00	
134 (.154+.170)½	= 21.71	
	42.89	× 1.0154 × .095 = 4.14 LB

STG'R 1836

84 × .077	= 6.47	
69 (.077+.122)½	= 6.91	
58 (.122+.154)½	= 8.00	
134 (.154+.170)½	= 21.71	
	43.05	× 1.0154 × .095 = 4.15 LB

STG'R 1839

85 × .077	= 6.54	
69 (.077+.122)½	= 6.87	
58 (.122+.154)½	= 8.00	
134 (.154+.170)½	= 21.71	
	43.12	× 1.0154 × .095 = 4.16 LB

STG'R 1842

87 × .077	= 6.70	
69 (.077+.170)½	= 6.87	
58 (.122+.154)½	= 8.00	
134 (.154+.170)½	= 21.71	
	43.28	× 1.0154 × .095 = 4.17 LB

STG'R 1845

88 x 077 = 6.78
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
134 (154+170)½ = 21.71
43.36 x 1.0154 x 095 = 4.18 LB

STG'R 1848

90 x 077 = 6.93
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
135 (154+170)½ = 21.87
43.67 x 1.0154 x 095 = 4.21 LB

STG'R 1851

91 x 077 = 7.01
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
135 (154+170)½ = 21.87
43.75 x 1.0154 x 095 = 4.22 LB

STG'R 1854

93 x 077 = 7.16
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
135 (154+170)½ = 21.87
43.90 x 1.0154 x 095 = 4.23 LB

STG'R 1857

94 x 077 = 7.24
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
135 (154+170)½ = 21.87
44.14 x 1.0154 x 095 = 4.26 LB

STG'R 1860

95 x 077 = 7.32
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
136 (154+170)½ = 22.03
44.22 x 1.0154 x 095 = 4.27 LB

STG'R 1863

96 x 077 = 7.39
69 (077+122)½ = 6.87
58 (122+154)½ = 8.00
136 (154+170)½ = 22.03
44.29 x 1.0154 x 095 = 4.27 LB

54.47

BAY 3

1866 STG'R
166 × 077 = 12.78
58(077+.122)½ = 5.77
136(.122+.130)½ = 17.14
35.69 × 1.0154 × 095 = 3.44 LB

1869 STG'R
168 × 077 = 12.94
58(077+.122)½ = 5.77
136(.122+.130)½ = 17.14
35.85 × 1.0154 × 095 = 3.46 LB

1872 STG'R
170 × 077 = 13.09
58(077+.122)½ = 5.77
136(.122+.130)½ = 17.14
36.00 × 1.0154 × 095 = 3.47 LB

1875 STG'R
171 × 077 = 13.17
58(077+.122)½ = 5.77
137(.122+.130)½ = 17.20
36.20 × 1.0154 × 095 = 3.49 LB

1878 STG'R
172 × 077 = 13.24
58(077+.122)½ = 5.77
137(.122+.130)½ = 17.20
36.27 × 1.0154 × 095 = 3.50 LB

1881 STG'R
173 × 077 = 13.32
58(077+.122)½ = 5.77
137(.122+.130)½ = 17.26
36.35 × 1.0154 × 095 = 3.51 LB

1884 STG'R
175 × 077 = 13.48
58(077+.122)½ = 5.77
137(.122+.130)½ = 17.26
36.51 × 1.0154 × 095 = 3.52 LB

1887 STG'R
176 × 077 = 13.65
58(077+.122)½ = 5.77
137(.122+.130)½ = 17.26
36.58 × 1.0154 × 095 = 3.53 LB

1890 STG'R

178 x.077 = 13.71
58 (.077+.122)½ = 5.77
138 (.122+.130)½ = 17.39
36.87 x 1.0154 x.095 = 3.56 LB

1893 STG'R

179 x.077 = 13.78
58 (.077+.122)½ = 5.77
138 (.122+.130)½ = 17.39
36.94 x 1.0154 x.095 = 3.56 LB

1896 STG'R

181 x.077 = 13.94
58 (.077+.122)½ = 5.77
138 (.122+.130)½ = 17.39
37.10 x 1.0154 x.095 = 3.58 LB

1899 STG'R

183 x.077 = 14.09
58 (.077+.122)½ = 5.77
138 (.122+.130)½ = 17.39
37.25 x 1.0154 x.095 = 3.59 LB

1902 STG'R

184 x.077 = 14.17
58 (.077+.122)½ = 5.77
139 (.122+.130)½ = 17.51
37.45 x 1.0154 x.095 = 3.61 LB

1905 STG'R

186 x.077 = 14.32
57 (.077+.122)½ = 5.77
139 (.122+.130)½ = 17.51
37.60 x 1.0154 x.095 = 3.63 LB

1908 STG'R

187 x.077 = 14.40
57 (.077+.122)½ = 5.77
139 (.122+.130)½ = 17.51
37.68 x 1.0154 x.095 = 3.63 LB

1911 STG'R

188 x.077 = 14.48
58 (.077+.122)½ = 5.77
139 (.122+.130)½ = 17.51
37.76 x 1.0154 x.095 = 3.64 LB

56.72

BAY 4

1914 STG'R
247 x 077 = 19.02
140(077+085)½ = 11.34
30.36 x1.0154x095 = 2.93 LB

1917 STG'R
249 x 077 = 19.17
140(077+085)½ = 11.34
30.51 x1.0154x095 = 2.94 LB

1920 STG'R
250x 077 = 19.25
140(077+085)½ = 11.34
30.59 x1.0154x095 = 2.95 LB

1923 STG'R
252 x 077 = 19.40
141(077+085)½ = 11.42
30.82x 1.0154x095 = 2.97

1926 STG'R
254x 077 = 19.56
141(077+085)½ = 11.42
30.98 x 1.0154x095 = 2.99

1929 STG'R
256x 077 19.71
141(077+085)½ = 11.42
31.13 x 1.0154x095 = 3.00

1932 STG'R
258x 077 = 19.87
141(077+085)½ = 11.42
31.29 x 1.0154x095 = 3.02

1935 STG'R
259x 077 = 19.94
142(077+085)½ = 11.50
31.44 x 1.0154x095 = 3.03

12/15

1938 STG'R

260 × 077 = 20.02
142(077+095)½ = 11 50
31.52 × 1.0154 × 095 = 3.04 LB

1941 STG'R

262 × 077 = 20.17
142(077+095)½ = 11 50
31.67 × 1.0154 × 095 = 3 06

1944 STG'R

263 × 077 = 20 25
142(077+095)½ = 11.50
31.75 × 1.0154 × 095 = 3 06

1947 STG'R

264 × 077 = 20.33
143(077+095)½ = 11.58
31 91 × 1.0154 × 095 = 3.08

1950 STG'R

266 × 077 = 20.48
143(077+095)½ = 11.58
32 06 × 1.0154 × 095 = 3 09

1953 STG'R

268 × 077 = 20.64
143(077+095)½ = 11 58
32.22 × 1.0154 × 095 = 3.11

1956 STG'R

269 × 077 = 20 71
143(077+095)½ = 11 58
32 29 × 1.0154 × 095 = 3.11

45.38

BAY 5

1959 STG'R

144 x.077	=	11.09
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
143 (.122 + .130)½	=	18.02
	43.06 x 1.0154 x .095 =	4.15 LB

1962 STG'R

146 x .077	=	11.24
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
143 (.122 + .130)½	=	18.02
	43.21 x 1.0154 x .095 =	4.17 LB

1965 STG'R

148 x .077	=	11.40
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
143 (.122 + .130)½	=	18.02
	43.37 x 1.0154 x .095 =	4.18 LB

1968 STG'R

149 x .077	=	11.47
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
143 (.122 + .130)½	=	18.02
	43.44 x 1.0154 x .095 =	4.19 LB

1971 STG'R

151 x .077	=	11.63
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
144 (.122 + .130)½	=	18.14
	43.72 x 1.0154 x .095 =	4.22 LB

1974 STG'R

153 x .077	=	11.78
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
144 (.122 + .130)½	=	18.14
	43.97 x 1.0154 x .095 =	4.23 LB

1977 STG'R

154 x .077	=	11.86
69 (.077 + .122)½	=	6.87
58 x .122	=	7.08
144 (.122 + .130)½	=	18.14
	43.95 x 1.0154 x .095 =	4.24 LB

1980 STG'R

156 × 077 = 12 01
69 (077+.122)½ = 6.87
58 ×.122 = 7 08
144 (122+.130)½ = 18.14
44.10 × 1 0154 × 095 = 4.25 LB

1983 STG'R

157 × 077 = 12 09
69 (077+.122)½ = 6.87
58 × 122 = 7 08
144 (122+.130)½ = 18.14
44.18 × 1 0154 × 095 = 4 26 LB

1986 STG'R

158 × 077 = 12.17
69 (077+.122)½ = 6.87
58 (122) = 7 08
145 (122+.130)½ = 18 27
44 39 × 1.0154 × 095 = 4.28 LB

1989 STG'R

159 × 077 = 12.24
69 (077+.122)½ = 6 87
58 ×.122 = 7 08
145 (122+.130)½ = 18.27
44.46 × 1 0154 × 095 = 4 29 LB

1992 STG'R

160 × 077 = 12.32
69 (077+.122)½ = 6 87
58 × 122 = 7 08
145 (122+.130)½ = 18.27
44.54 × 1.0154 × 095 = 4.30 LB

1995 STG'R

161 × 077 = 12 40
69 (077+.122)½ = 6 87
58 ×.122 = 7 08
145 (122+.130)½ = 18 27
44.62 × 1 0154 × 095 = 4.30 LB

1998 STG'R

163 × 077 = 12.65
69 (077+.122)½ = 6.87
58 ×.122 = 7.08
146 (122+.130)½ = 18 40
44.90 × 1 0154 × 095 = 4 33 LB

15/15

2001 STG'R

164 x .077	=	12.63
69 (.077+.122)½	=	6 87
58 x .122	=	7.08
146 (122+.130)½	=	18 40
44.98 x 1.0154 x .095	=	4.34 LB

2004 STG'R

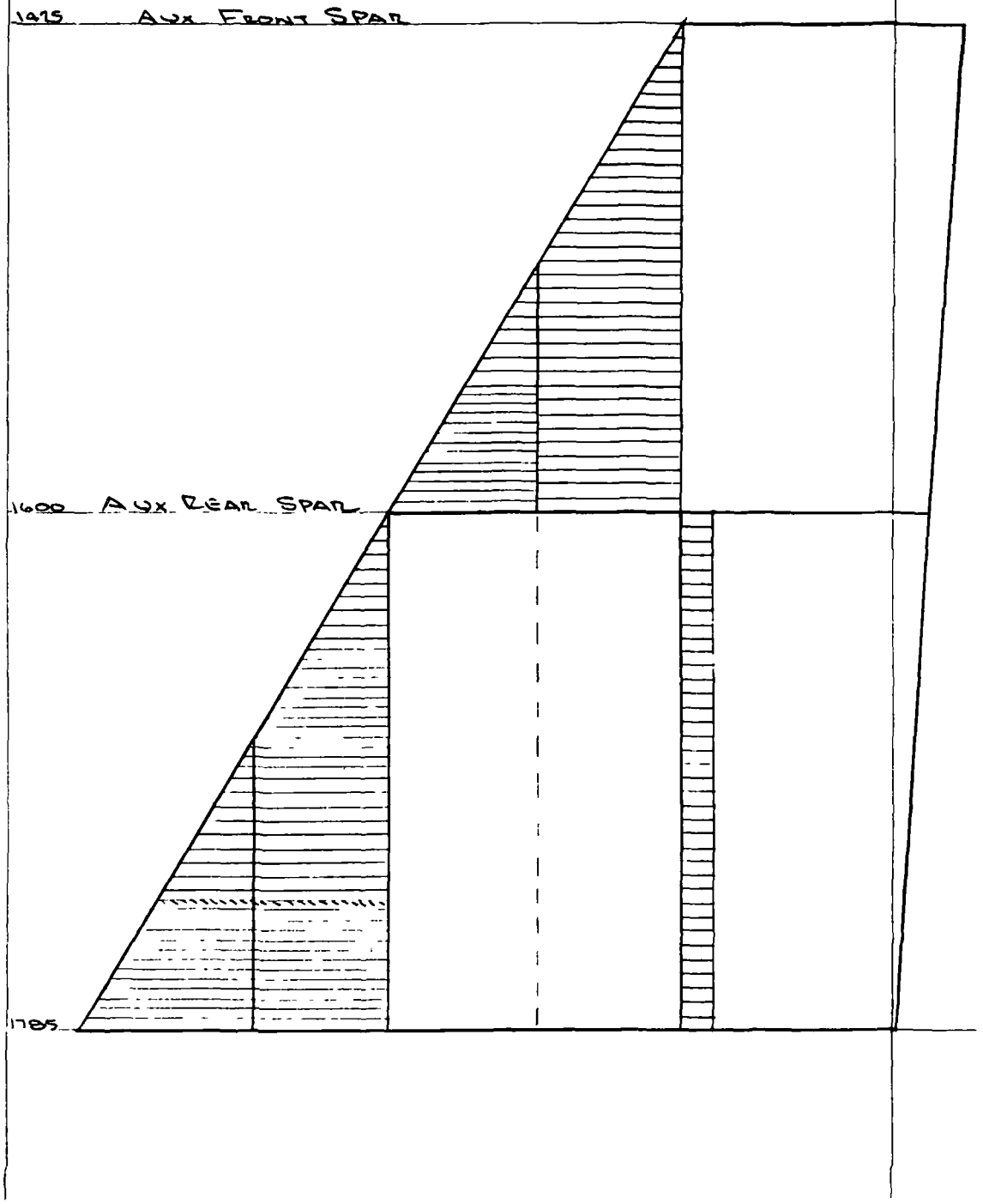
165 x .077	=	12 71
69 (077+.122)½	=	6 87
58 x .122	=	7 08
146 (122+.130)½	=	18.40
45.06 x 1 0154 x .095	=	4 35 LB

TOTAL IDEAL STRINGERS		290 LB
TOTAL IDEAL COVER		559 LB
TOTAL SKIN & STG'R		849 LB
RIVETS $\frac{85600}{1025 \times 3}$ x .00072		33 LB

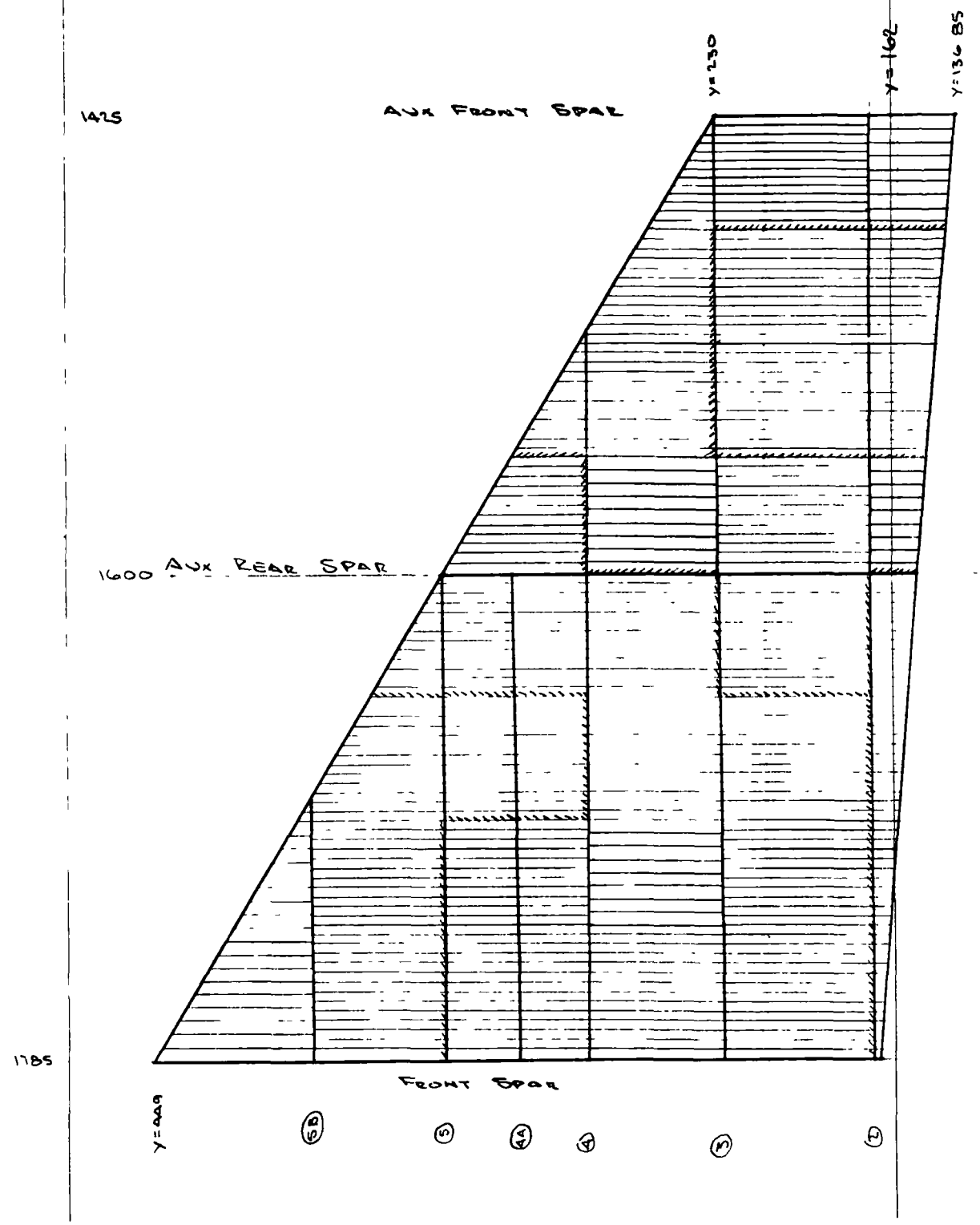
NON OPTIMUM IS COMPUTED FROM LWR SURFACE 2.1-28

SKIN	1.15 x 559 =	633 LB	ITEM 4
STG'R	1.15 x 290 =	344 LB	13

5-21-71	J GARRISON	WING	FWD - LWR COVER



5-11-71	J GARRISON	WING	FWD - TOP COVER



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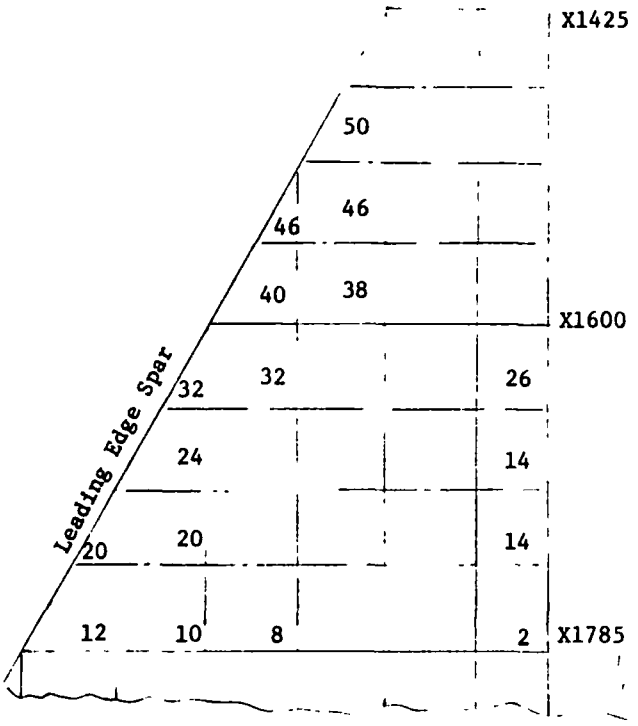
FORWARD WING - BOTTOM COVER
SIZING INFORMATION



Panel	Skin Thickness In.	Stiffener Pitch *
2	.05	3.5
8	.03	3.5
10	.02	3.5
12	.02	3.5
14	.05	3.5
20	.03	5.0
24	.03	3.5

Panel	Skin Thickness In.	Stiffener Pitch *
26	.050	3.5
32	.030	5.0
38	.030	5.0
40	.030	3.5
46	.030	5.0
50	.030	5.0

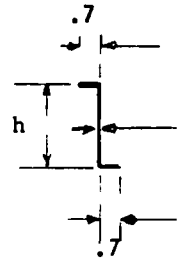
* The weight of the stiffening is 40% of the skin weight.

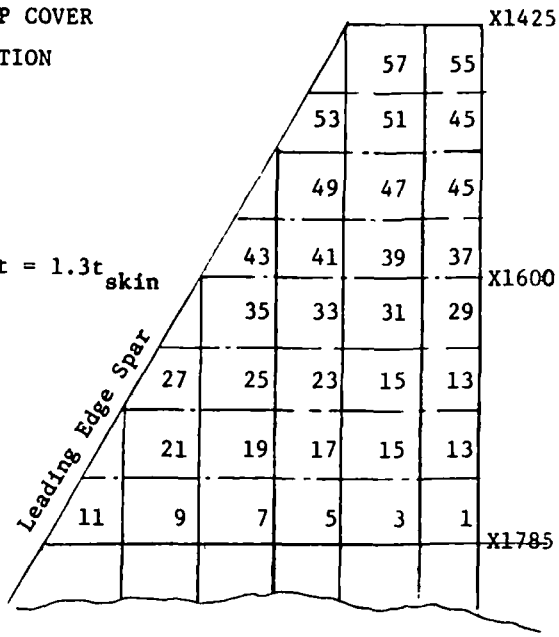
MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

FORWARD WING - TOP COVER

SIZING INFORMATION

Type	h
1	4.5
2	3.5
3	3.0
4	2.5
5	2.0





All dimensions are in inches

Panel	Skin Thickness	Stiffeners	
		Pitch	Type
1	.05	3.5	3
3	.04	3.5	3
5	.04	3.5	5
7	.04	3.5	5
9	.03	3.5	5
11	.03	5.0	5
13	.05	3.5	3
15	.04	3.5	3
17	.04	5.0	5
19	.04	3.5	4
21	.03	3.5	5
23	.04	3.5	5
25	.03	3.5	4
27	.03	3.5	4

Panel	Skin Thickness	Stiffeners	
		Pitch	Type
29	.05	3.5	3
31	.03	3.5	3
33	.04	3.5	4
35	.04	3.5	4
37	.03	5.0	3
39	.03	3.5	3
41	.03	5.0	2
43	.04	3.5	3
45	.02	3.5	3
47	.02	3.5	2
49	.03	3.5	1
51	.02	3.5	2
53	.03	3.5	1
55	.03	5.0	1
57	.03	3.5	1

J GARRISON	WING	FWD WING	Y

LWR COVER

AUX FRONT SPAR TO AUX REAR SPAR

$A = 110 * 175 * \frac{1}{2} = 9610\ IN^2$

IDEAL WT: $.030 * 9610 * .164 = 47.3$ LB

AUX REAR SPAR TO FRONT SPAR

$18 * 185 * .050 * .164$	$= 27.3$ LB
$38 * 185 * .050 * .164$	$= 57.5$ LB
$35 * 140 * \frac{1}{2} * .030 * .164$	$= 29.4$ LB
$(85 + 113)\frac{1}{2} * 47 * .020 * .164$	$= 15.3$ LB
TOTAL	177 LB/SIDE

FOR INTERCOSTALS USE THE SAME PERCENTAGE AS LWR T/B STIFFENERS

$\frac{171}{503} = 34\%$

$177 * .34 = 60$ LB/SIDE

FOR NON OPTIMUM USE 15%

SKIN $177 * 1.15 = 204$ LB

STG'R $60 * 1.15 = 69$ LB

Upper Skin Pad

030 Skin Avg Pitch = 3.5 in

$$\frac{3.5 \times 030 + .75 \times 020}{3.5} = 034 \text{ or } 14.3\%$$

020 Skin Avg Pitch = 3.5 in

$$\frac{3.5 \times 020 + .75 \times 030}{3.5} = 026 \text{ or } 32.1\%$$

040 Skin Avg Pitch = 3.5 in

$$\frac{3.5 \times 040 + .75 \times 010}{3.5} = 042 \text{ or } 5\%$$

Upr Cover
Fwd of Aux Rear Spar

$39 \times 44 \times 030 \times .164 \times 1.143$	=	20 8
$84 \times 88 \times 020 \times .164 \times 1.321$	=	32 0
$85 \times 43 \times 030 \times .164 \times 1.143$	=	20 6
$46 (175+93)\frac{1}{2} \times 030 \times .164 \times 1.143$	=	39.7
$(47+30)\frac{1}{2} \times 46 \times 040 \times .164 \times 1.05$	=	13 3
$48 \times 30 \times \frac{1}{4} \times 040 \times .164 \times 1.05$	=	5 0

Sub Total 126 4 LB/SIDE

Upr Cover
Front Spar to Aux Rear Spar

$115 \times 185 \times \frac{1}{2} \times 030 \times 164 \times 1.143$	=	59 8
$56 \times 138 \times 040 \times 164 \times 1.05$	=	53 3
$56 \times 47 \times 030 \times 164 \times 1.143$	=	14 8
$111 \times 100 \times 040 \times .164 \times 1.05$	=	107 0
$53 \times 95 \times 040 \times 164 \times 1.05$	=	16.4
$58 \times 46 \times 030 \times .164 \times 1.143$	=	13 5
$(25+7)\frac{1}{2} \times 185 \times 050 \times .164$	=	24.3

Sub Total 192.8 LB/SIDE

Total Skin = 319.2 LB/SIDE
$319 \times 1.15 = 367$ LB Item 6

UPR COVER INTER COSTALS

USE NOMINAL VALUE AS AN AVERAGE

t_{SKIN} .030
PITCH 3.5
t_{INTCL} 1.3 t_S
h 3.0
FLANGE .75

$$\frac{.030 * 3.5 + 4.5 * .030 * 1.3}{3.5} = .080$$

$$\frac{.080}{.030} = 267\%$$

THIS APPLIES TO BASIC SKIN

∴ REMOVE PAD CORRECTION

$$\frac{267}{114.3} = 233\% \ \bar{t}$$

ADD 133% FOR INTERCOSTALS

$319 * 1.33 = 424$ LB/SIDE

$424 * 1.15 = 487$ LB ITEM 15

FWD WING

LWR SURFACE

ADD MIN SHELL MATERIAL OVER ABES AND MLG CUT-OUT FOR CORRELATION TO MAC 747 ESTIMATION FOR DOORS

MLG DOOR - GROSS AREA ~ 120 FT²

USE .020 SKIN W 34% STG'R

120 * 144 * .020 * .164 = 57 LB

STG'R 57 * .34 = 20 LB

TOTAL = 77 LB/SIDE

ABES DOOR 1 @ 134 FT²
1 @ 102 FT²

134 * 144 * .020 * .164 = 63 LB

STG'R 63 * .34 = 22 LB

TOTAL 85 LB/SIDE

102 * 144 * .020 * .164 = 48 LB

STG'R 48 * .34 = 16 LB

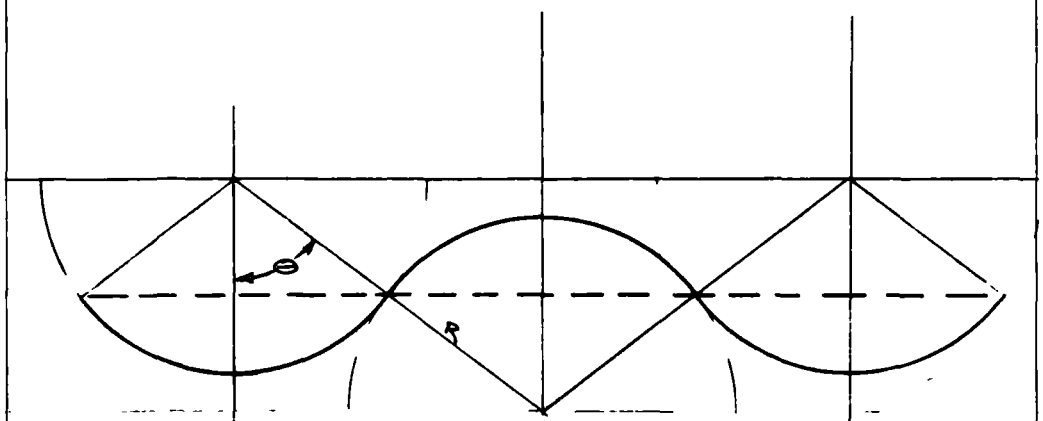
TOTAL 64 LB/SIDE

TOTAL LWR SURFACE
SKIN: 204 + 128(57+63+48) = 420 LB ITEM 10
STG'R 69 + 128(20+22+16) = 143 LB " 19

J GARRISON	WING	CURVED CORRUGATIONS

PROJECTED L = R SIN Θ

DEVELOPED L = $2\pi R\left(\frac{\Theta}{360}\right)$



THE CORRELATION

TRUE LENGTH = $\frac{2\pi \frac{\Theta}{360}}{\sin\Theta}$

IS USED FOR ALL CORRUGATED WEBS

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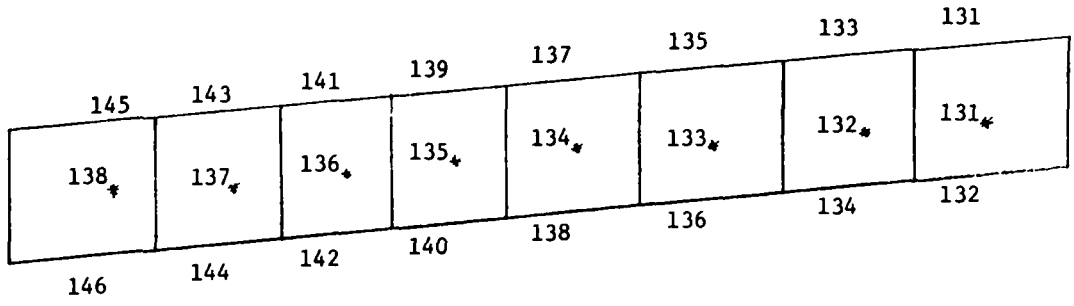
STRUCTURAL SIZING L.E. SPAR



Item	Panel*	Circular Arc Corrugation		
		θ°	R-In.	t-In.
L.E	138	87	1.6	.024
Spar	137	"	1.2	.020
	136	"	1.1	.020
Web	135	"	1.3	.022
	134	"	1.3	.023
	133	"	1.2	.021
	132	"	1.1	.020
	131	"	1.1	.020

Item	Bar	Area-In^2
L.E.	146	.16
Spar	144	.13
Bottom	142	.16
Cap	140	.12
	138	.13
	136	.11
	134	.10
	132	.10

Item	Bar	Area-In^2
L.E.	145	.16
Spar	143	.13
Top	141	.16
Cap	139	.12
	137	.13
	135	.11
	133	.10
	131	.10

J GARRISON	WING	FWD WING	Y

LEADING EDGE SPAR GAL AV TL

$\Theta = 87°$ $t_L = 1.52$ * PROJECTION

BAY	L UPR	L LWR	A UPR	A LWR	WT UPR	WT LWR	h	t	WT
1	85	85	.16	.16	2.2	2.2	82	024	15.8
2	63	67	.13	13	1 3	1 3	31	020	9.5
3	58	67	.16	.16	1.5	1 5	34	020	9.5
4	67	67	.12	.12	1.3	1.3	36	022	12.9
5	58	59	.13	.13	1 2	1 2	35	023	11.5
6	62	62	.11	.11	1.1	1.1	32	021	10 1
7	62	62	.10	.10	1.0	1 0	33	020	9.4
8	60	61	.10	.10	1 0	1.0	46	020	13.5
		Σ			10.6 LB	10.6 LB			92.7 LB

CAPS 21.2 LB/SIDE

WEB 92.7 LB/SIDE

TOTAL - 114 * 1.28 = 146 LB ITEM 23

Torque Box

L E SPAR

CAP AREA 3 * 024 = .072 in²

260 * 072 * .164 = 3.1 LB
3.1 LB

260 * 30 * 020 * 152 * .164 = 39 LB

TOTAL = 45 LB

20% 13 LB

58 LB / SIDE Item 25

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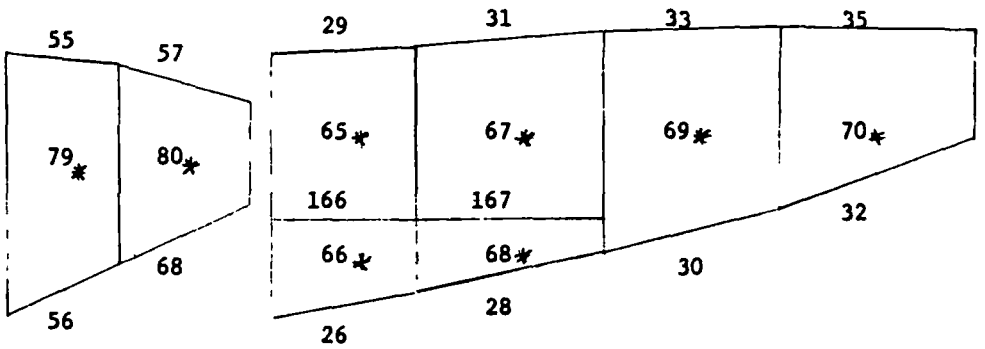
STRUCTURAL SIZING - AUXILIARY SPARS



ITEM	PANEL *	CIRCULAR ARC CORRUGATION		
		θ°	$R_{IN.}$	$t_{IN.}$
A.S-(FRONT) WEB	79	87	2.8	.031
	80	87	2.2	.033
A.S-(REAR) WEB	65	-87	2.1	.075
	66	84	1.5	.058
	67	87	2.2	.069
	68	71	1.7	.075
	69	87	2.4	.038
	70	87	2.1	.029

ITEM	BAR	AREA IN^2	ITEM	BAR	AREA IN^2
A.S-(FRONT) TOP CAP	55	.32	A.S-(FRONT) BOTTOM CAP	56	.32
	57	.30		58	.30
A.S-(REAR)	29	.81	A.S-(REAR)	26	.47
	31	.77		28	.72
TOP CAP	33	.38	BOTTOM CAP	30	.38
	35	.24		32	.24

AUX FRONT SPAR – REQUIRED SIDES ARE LISTED WITH THE TABULATION FOR RIBS ON PAGES

INNER BAY $\Theta = 87°$ $t_L = 1.52$ PROJECTED AREA

WEB

$.031 * 1.52 * 36 * 75 * \frac{1}{2} * .16 = 10.2$ LB

OUTER BAY $\Theta = 87°$ $t_L = 1.52$

WEB

$.033 * 84 * 62 * 1.52 * .16 = 41.8$ LB

TOTAL = 52 LB/SIDE

CAPS - UPR

$84 * .30 * .16 = 4.0$

LWR

$120 * .31 * 16 = 6.0$

TOTAL 10LB/SIDE

WT = $1.25(52+10) = 79$ LB ITEM 28

AUX REAR SPAR

UPPER CHORD L = 178 IN

AVG X-SEC = .81
.77
.88
.24
4 | 2.20
55 IN

WT = 178 * .55 * .160 = 15.7 LB

LWR CHORD L = 228 IN

AVG X-SEC = .47
.72
.38
.24
4 | 1.81
.453

WT = 228 * .453 * .16 = 16.5 LB

TOTAL = 32.2 LB/SIDE

WEBS θ = 87° t_c = 1.52

PANEL 1
65 * 30 * 075 * 1.52 * .16 = 35.5 LB

PANEL 2
73 * 65 * 069 * 1.52 * 16 = 79.7 LB

PANEL 3
45 * 71 * 038 * 1.52 * .16 = 29.6 LB

PANEL 4
55 * 60 * 029 * 1.52 * .16 = 23.3 LB

TOTAL = 168.1 LB/SIDE

WT = (168 + 32) 1.28 = 256 LB ITEM 31

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Wing Main Box - Spar Sizes - Mat'l Ti-6AL-4V

FRONT SPAR (X1785)

Y Sta. In.	Web			Cap Area	
	Depth In.	Gage In.	R In.	Top In^2	Bottom In^2
146	58	.090	2.04	1.175	0.68
184	58	.075	2.42	1.105	0.62
240	64	.063	2.42	0.99	0.52
291	63.5	.055	2.42	0.86	0.42
341	59	.041	1.60	0.49	0.33
401	50	.022	1.60	0.15	0.15
461	32	TAPER .034		0.13	0.13

Vert. Rib Attachments = 0.19 in^2

Note Θ = 77.5° constant throughout.

REAR SPAR (X2009)

Y Sta. In.	Web			Cap Area	
	Depth In.	Gage In.	R In.	Top_2 In^2	Bottom In^2
146	14.5	.048	1.9	.198	.178
184	23	TAPER .030		.192	.173
240	27	.028		.186	.168
291	30	.028 / .032	1.9 / 2.24	.179	.163
341	31			.173	.157
401	28.5			.165	.151
461	28.5			.157	.144
511	27	.032	2.24	.151	.139

Vert. Rib Attachments = 0.08 in^2

J GARRISON	WING	TORQUE BOX	Y

FRONT SPAR

CORRUGATED WEB $\Theta = 77.5°$

DEVELOPED L = $2\pi R(\Theta/360)$
PROJECTED L = $R \sin\Theta$

LENGTH CORRECTION = $\frac{2\pi\Theta/360}{\sin\Theta} = \frac{2\pi * 77.5/360}{.9763} = 1.385$

GEOMETRY

THE WEB WAS SIZED IN 6-6-2 TITANIUM BUT THE SELECTED MATERIAL IS 6-4 TITANIUM. AS THE WEB IS MODULUS CRITICAL, RATIO t BY

$\frac{E_{662}}{E_{64}} = \frac{16.5}{16} = 1.032$

BAY 1 RUNS FROM ROOT RIB TO RIB 2A
UPR CAP L = 16 IN
LWR CAP L = 24 IN

WEB A = $(54+60)\frac{1}{2} * 13.3 = 692$
$(7.5+10)50 * \frac{1}{2} = 312$
$1004\ in^2 * 1.385 = 1385\ in^2$

BAY 2 RIB 2A TO RIB 3
UPR CAP L = 46 IN
LWR CAP L = 44 IN

WEB A = $(54+62)\frac{1}{2} * 44 = 2550\ in^2 * 1.385 = 3530\ in^2$

BAY 3 RIB 3 TO RIB 4
UPR CAP L = 54.3
LWR CAP L = 65.3

WEB A = $(62+61.5) * \frac{1}{2} * 530 = 3270\ in^2 * 1.385 = 4520\ in^2$

BAY 4 RIB 4 TO RIB 5
UPR CAP L = 57.3
LWR CAP L = 57.3

WEB A = $(61.5+56.5)\frac{1}{2} * 57.3 = 3380\ in^2 * 1.385 = 4680\ in^2$

2/

BAY 5 RIB 5 TO SC
UPR CAP L = 67
LWR CAP L = 67

WEB A = (56.5 + 45) ½ * 67 = 3385 * 1385 = 4680 in²

BAY 6 RIB SC TO LE SPAR
UPR CAP L = 45.8
LWR CAP L = 46.0

WEB A = (45 + 33.5) ½ * 45.4 = 1780 * 1385 = 2470 in²

WEIGHTS

BAY	UPR CAP L	UPR CAP x-SEC 1	UPR CAP x-SEC 2	UPR CAP WT	LWR CAP L	LWR CAP x-SEC 1	LWR CAP x-SEC 2	LWR CAP WT	WEB A	WEB t_1	WEB t_2	WEB WT
1	16	1.175	1.105	2.92	24	.68	.62	2 50	1385	078	078	17.7
2	46	1.105	99	7.71	44	62	.52	4 01	3580	075	075	43.9
3	59.3	.99	.86	8.04	653	.52	.42	4 91	4520	063	063	47.1
4	57.3	.86	.49	6 19	573	.42	.33	3.49	4680	055	055	42.2
5	67	.49	15	3.43	67	.33	.15	2 57	4680	041	041	31.5
6	45 8	15	.13	1 02	46	.15	.13	1.03	2470	022	034	11 3
Σ				29 3				18.5				193 2

291 LB

3/

RIB ATTACH STIFF

LOC	L	TOTAL AVG X-SEC	WT
LE	33	.19	1.00
5D	37		1.12
5C	45		1.37
5B	50		1.52
5A	54		1.64
5	55		1.67
4A	58		1.76
4	60		1.82
3A	63		1.92
3	62		1.88
2B	52		1.58
2A	54		1.64
2	50		1.52
1	50	.19	1.52

22 LB

TOTAL IDEAL SPAR = 263 LB

263 * 1.28 = 336 LB ITEM 34

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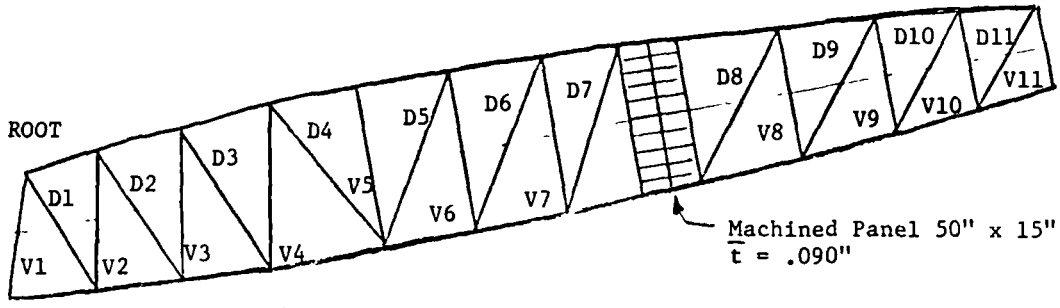
Wing Main Box Spar - X1865 - Mat'l Weldments are Ti-6AL-4V annealed.
Other members are Ti-6AL-6V-2Sn S.T.A.

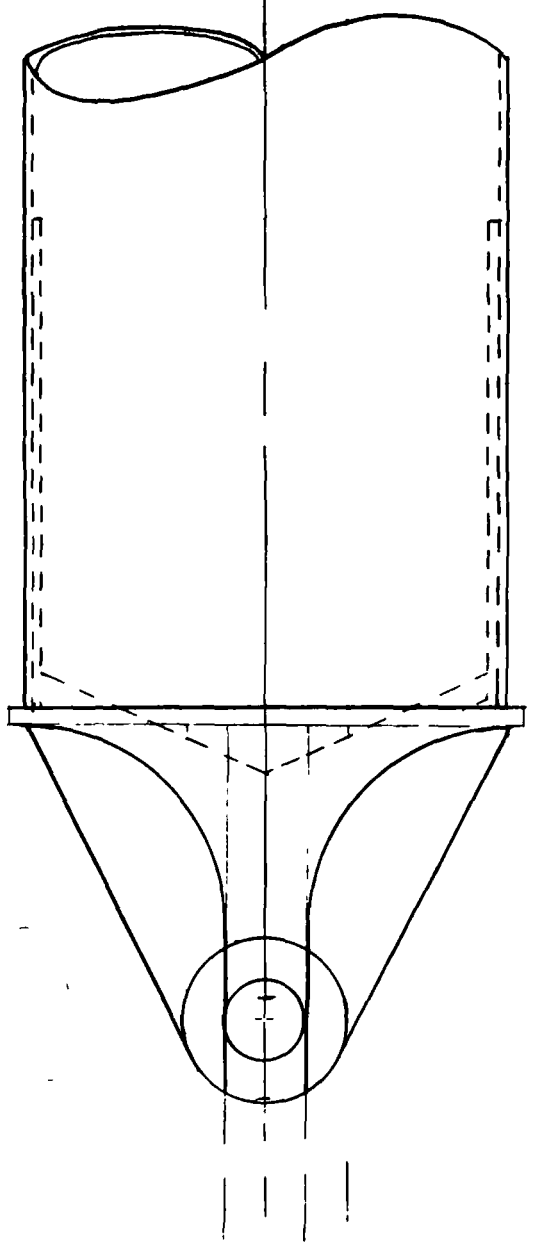


Verticals - 'V'			
Member	Length In.	Dia.-In.	Gage-In.
1	Part of Root Rib		
2	44.3	3.00	.048
3	49.3	3.46	.055
4	52.3	3.60	.058
5	54.2	2.80	.026
6	54.0	3.62	.051
7	52.0	3.39	.048
8	47.2	3.65	.051
9	44.0	3.34	.047
10	37.7	3.12	.044
11	31.5	2.64	.038

Diagonals - 'D'			
Member	Length In.	Dia.-In.	Gage-In.
1	42.5	3.25	.045
2	48.5	4.00	.057
3	52.5	4.30	.061
4	58.7	3.82	.055
5	61.8	3.75	.050
6	60.0	2.80	.045
7	59.0	3.00	.045
8	60.7	3.00	.057
9	58.0	3.00	.048
10	54.0	3.00	.043
11	51.0	3.00	.036

Top & Bottom Cap Area = 0.768 in^2 (each)

J GARRISON | WING | TYPICAL TUBE FTG



GAL AL ANNEAL
F_{TU} = 130
F_{SU} = 80

TUBE X-SEC = $3\pi \times .080 = .47$ in²

DESIGN AXIAL LOAD = .27 * 130 = 61 K

PIN SIZE = $\frac{61}{80 \times 2}$ = .38 IN²

$R = \left(\frac{.38}{\pi}\right)^{1/2}$ = .25 + .1 IN

USE A ½ IN PIN

t = ½ IN

WT = .050x2 85 π * 3 =	1.34
3*2.4 * ½ * ½ =	1.80
2.15*2*1.25²*½ =	.67
1.5²π * .25 =	1.77
	5.58 IN³ = .9 LB

L_{THEO} = 43 IN

TUBE WT THEO = .27 * 43 * .16 = 3.23 LB

TUBE TRUE L = 37 IN

TUBE TRUE WT = .27 * 37 * .16 = 2.78 LB

TOTAL = 2.78 + .9x2 = 4.58

FTG AS A % OF THEO TUBE = $\frac{4.58}{3.23}$ = 1.42

42% INCR OVER THEO TUBE

TO BE USED FOR ALL END FITTINGS

J GARRISON	WING	TORQUE BOX	Y

CENTER SPAR

USE THEORETICAL LENGTHS AND 42% FOR END FTGS.

THESE ARE IDEAL TUBES. NO ECCENTRICITY OR BEAM EFFECT. USE 25% FOR THIS AND CAP ATTACH FTG

MEMBER	DIAM	GAGE	LENGTH	WT
D-1	3.25	045	42.5	5 38
D-2	4.00	057	48.5	9.52
D-3	4 30	061	52.5	11.85
D-4	3 82	055	58.7	10.61
D-5	3 75	050	61 8	9 97
D-6	2 80	045	600	6.51
D-7	2 80	045	59 0	6.40
D-8	3 00	057	60 7	8.93
D-9	3 00	048	58.0	7 19
D-10	3 00	043	54 0	5 99
D-11	3.00	036	5/ 0	4.74

92.1 LBS/SIDE

$\pi * D * L * t * \rho * 1.67$

2/

MEMBER	DIAM	GAGE	LENGTH	WT
V-1	3 12	050	38.5	5.17
V-2	3 00	048	44.3	5 49
V-3	3.46	055	49.3	8.07
V-4	3 60	058	52.3	9 40
V-5	2 80	026	54 2	3 40
V-6	3.62	051	54 0	8.58
V-7	3 39	048	52 0	7.28
V-8	3 65	051	47 2	7 56
V-9	3.34	047	44 0	5 94
V-10	3.12	044	37.7	4.45
V-11	2 64	038	31 5	2.72

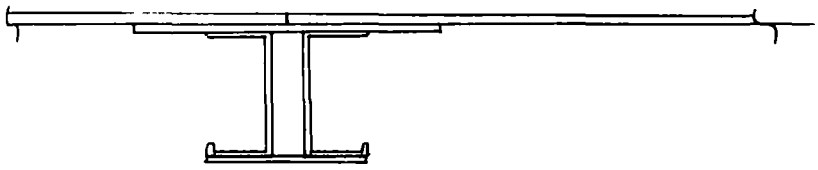
68.7 LB/SIDE

CENTER SPAR MACHINED PANEL

15 * 48 * 090 * .164 = 113

J GARRISON	WING	TORQUE BOX	Y

CENTER SPAR CAPS



X-SEC =	3.8 × .04	=	.152
	1.5 × .07 × 2	=	.210
	.8 × .07 × 4	=	.224
	.3 × .07 × 2	=	.042
	2 × .07	=	.140
			.768 IN² CONSTANT

UPR CAP L = 343 IN

WT = 343 × .768 × .166 = 43.2 LB

LWR CAP L = 355 IN

WT = 355 × .768 × .166 = 44.8 LB

TOTAL = 1.28 (43 + 45 + 11 + 68 + 92) = 202 LB Item 37

REAR SPAR

CORRUGATED WEB $\theta = 77.5°$

LENGTH CORRECTION = 1.385 (SEE FRONT SPAR)

BAY 1 ROOT RIB TO RIB 2A
UPR CAP L = 28
LWR CAP L = 29

WEB A = $(21+15.5)\frac{1}{2} * 28 = 511$ * 1.385 = 708_{in^2}

BAY 2 RIB 2A TO RIB 3
UPR CAP L = 54.5
LWR CAP L = 53.5

WEB A = $(21+27)\frac{1}{2} * 52.5 = 1260$ * 1.385 = 1745_{in^2}

BAY 3 RIB 3 TO RIB 4
UPR CAP L = 59
LWR CAP L = 63.8

WEB A = $(59+63.8)\frac{1}{2} * 28 = 1719$ * 1.385 = 2381_{in^2}

BAY 4 RIB 4 TO RIB 5
UPR CAP L = 57.3 IN
LWR CAP L = 57.5 IN

WEB A = $(29+28)\frac{1}{2} * 57.4 = 1636$ * 1.385 = 2266_{in^2}

BAY 5 RIB 5 TO RIB 5C
UPR CAP L = 67
LWR CAP L = 67.5

WEB A = $(28+27)67.2 * \frac{1}{2} = 1848$ * 1.385 = 2560_{in^2}

BAY 6 RIB 5C TO 5D
UPR CAP L = 30.5
LWR CAP L = 30.5

WEB A = $(27)(30.5) = 824$ * 1.385 = 1140_{in^2}

BAY 7 RIB 5D TO LE SPAR
UPR CAP L = 146.5
LWR CAP L = 146.5

WEB A = $(27+20)146.5 * \frac{1}{2} = 3443$ * 1.385 = 4768_{in^2}

2/

Weights

Bay	UPR CAP				LWR CAP				WEB			
	L	X-SEC 1	X SEC 2	WT	L	X-SEC 1	X-SEC 2	WT	A	t_1	t_2	WT
1	28	198	192	.87	29	178	.173	81	708	048	030	4.53
2	54.5	.192	186	1 66	535	173	168	1.46	1743	028	028	8.01
3	59	.186	.179	172	63 8	168	.163	1 69	2381	028	028	10 93
4	57 3	.179	.173	1 61	57.5	163	.157	1 47	2266	032	032	11 89
5	67	173	165	1 81	67.5	.157	151	1 66	2560	032	032	13 43
6	30.5	.165	.157	.78	30 5	.151	.144	.72	1140	032	032	5 98
7	146 5	.157	.151	3 61	146.5	144	.139	3 32	4768	032	032	25 02
				12.0				11.1				79 8

103.8

RIB ATTACH STRAP

LOC	L	AVG x-SOC	WT
LG	20	.08	.26
ACDS	22.5		.30
ACDS	23		.30
RIB6	25		33
RIB5D	27		.35
RIB5C	27		.35
RIB5B	27		.35
RIB5A	27		.35
RIB 5	27.5		.36
RIB 4A	28.5		.37
RIB4	29		.38
RIB 3A	28		.37
RIB 3	27		35
RIB 2B	25		.33
RIB 2A	21		28
RIB 1	15.5	.08	.20

5.23 LB

TOTAL IDEAL WT = 108 LB

WT = 1.28 × 108 = 137 LB ITEM 40

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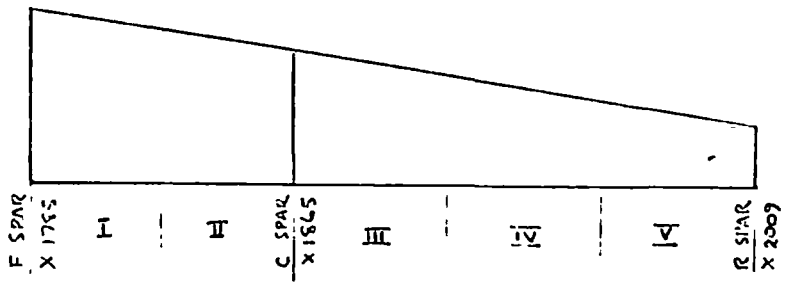
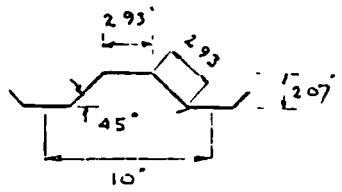
MAIN TORQUE BOX ROOT RIB

Summary of Structure Sizes



Web

Bay	t_w	$\bar{t}$
I	0.100	0.117
II	0.065	0.076
III-V	0.060	0.070

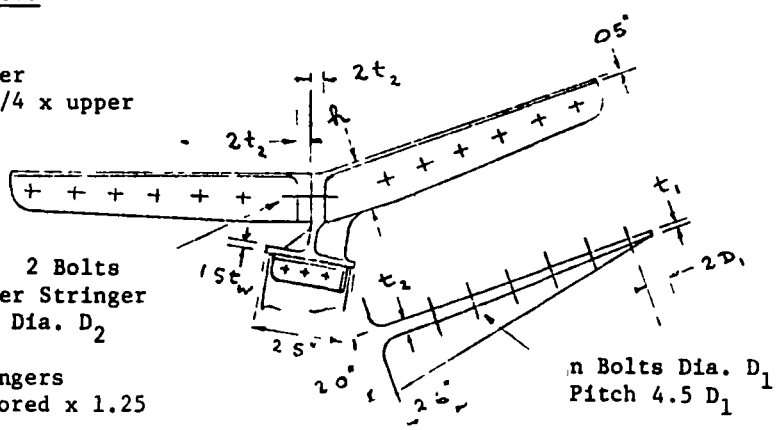


Mat'l Ti-6AL-6V-2Sn (S.T.A.)

Caps and Cover Splices

Upper shown
Total weight of lower cap and splices = 3/4 x upper

Mat'l
Ti-6AL-6V-2Sn
(S.T.A.)



2 Bolts
Per Stringer
Dia. D_2

n Bolts Dia. D_1
Pitch 4.5 D_1

Weight of splice fingers
as drawn to be factored x 1.25

Bay	D_1	n	t_1	t_2	h	D_2
I	1/4 in	9	.07 in	.18 in	1.5 in	3/8 in
II	0.189	7	.055	.10	1.25	5/16
IV, V	0.189	4	.05	.05	1.25	5/16
III	Weight of Bay III		= Mean of	II and IV		

WEB 6-6-2 Ti

BAY I FS 1785 - 1825 $\bar{t}$ = .117
h_1 = 43" h_2 = 38

$W_T = (43+38)\frac{1}{2} * 40 * .117 * .164 = 31$ LB

BAY II FS 1825 - 1865 $\bar{t}$ = .076
h = 38 h_2 = 33

$W_T = (38+33)\frac{1}{2} * 40 * .076 * .164 = 17.7$ LB

BAY III FS 1865 - 1937 ADD 50% FOR M/M
h = 33 h = 22

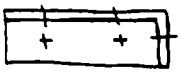
$W_T = (33+22)\frac{1}{2} * 72 * .070 * .164 * 1.5 = 34.2$ LB

BAY IV FS 1937 - 2007
h = 22 h = 15

$W_T = (22+15)\frac{1}{2} * 70 * .070 * .164 = 14.9$ LB

WEB 97.8 LB/10^3

WEB BATH TUB FTG



$V = 29 * 2 * 1.25 * 1.5 * .3 = 32.7$ t

FASTENERS 6 @ (.006+.004) = .06 LB

BAY I

$\frac{40}{5} * .117 * .164 * 32.7 + .06 * 8 = 5.5$ LB

BAY II

$\frac{40}{5} * .076 * .164 * 32.7 + .06 * 8 = 3.8$ LB

BAY III

$1.5 * \frac{73}{5} * .070 * .164 * 32.7 + .06 * \frac{23 * 1.5}{5} = 9.6$ LB

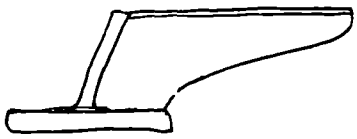
BAY IV

$\frac{28}{5} * .070 * .164 * 32.7 + .06 * \frac{28}{5} = 6.4$ LB

UPR WEB ATTACH 25.3 LB/10^3

2/

UPR WEB CAP INBD



BAY I

2.5 * .117 * 1.5 * 3	=	1.32
2.0 * .117 * 2 * 3	=	1.40
1 * 050 * 12.1	=	.61
½ (.07 * 1 + 18 * 1.5) 12.1	=	2.06

5.39 * 164 = .88 LB/3 IN PITCH

UPR CAP WEB - OUTB'D

BAY I

2.0 * 117 * 2 * 3	=	1.40
1 * 050 * 12.1	=	.61
½ (07 * 1 + 18 * 1.5) 12.1	=	2.06

4.07 * .164 = .67 LB/3 IN PITCH

FASTENERS

18 @ .01 = .18
2 @ 024 = .05

TOTAL = $\frac{40}{3}$ (.88 + .67 + .23) = 24 LB

24 * 1.25 = 30 LB

3/

BAY II INB'D

25 * 076 * 1.5 * 3	=	.86
20 * 076 * 2 * 3	=	.91
1 * 050 * 8.1	=	.41
8.1 (.75 * 055 + 1.25 * .10) ½	=	.68

2.86 * .164 = .47 LB/3 IN PITCH

OUTB'D

2.0 * 076 * 2 * 3	=	91
1 * 050 * 8.1	=	.41
8.1 (.75 * 055 + 1.25 * .1) ½	=	.68

200 * .164 = .33 LB/3 IN PITCH

FASTENERS

19 * 007	=	10
2 * 024	=	05
		.15 LB/ PITCH

TOTAL = $\frac{40}{3}$ (.47 + .33 + .15) = 12.7 LB

12.7 * 1.25 = 15.9 LB

BAY III AVG OF II & IV

.95
.69
1.64/2 = .82 LB/ 3 IN PITCH

$\frac{48}{3}$ * .82 = 13 LB

13 * 1.25 = 16 LB

4/

BAY 5 & BAY 4

INB'D

25 *.070 *1.5 *3 : .79
20 *.070 *2 *3 = .84
1 *050 *55 = 28
½ (75+125) 050 *5.5 = .28

2.19 *.164 = .36 LB/3IN PITCH

OUT B'D

2.0 *.070 *2 *3 = .84
1 *050 *5.5 = .28
½ (75+125) 050 *5.5 = 29

140 *.164 = .22 LB/3IN PITCH

FASTENERS
20 024 : 05
80 007 : .06
.11 LB / 3IN PITCH

TOTAL : .69 LB/3IN PITCH

BAY 4 & 5 L= 95 IN

$\frac{95}{3}$ * 69 = 22 LB

WT = 22 * 125 = 28 LB

SKIN SPLICE STRAP

222 * 6 *050 *.164 = 11 LB

5/

SUMMARY

WEB		98
UPR CAP		126
FTG	25	
FINGER	90	
STRAP	11	
LWR CAP		95
TOTAL		3194/SIDE
NON OPTIMUM 28%		89
TOTAL		408 LB/SIDE

ITEM 46

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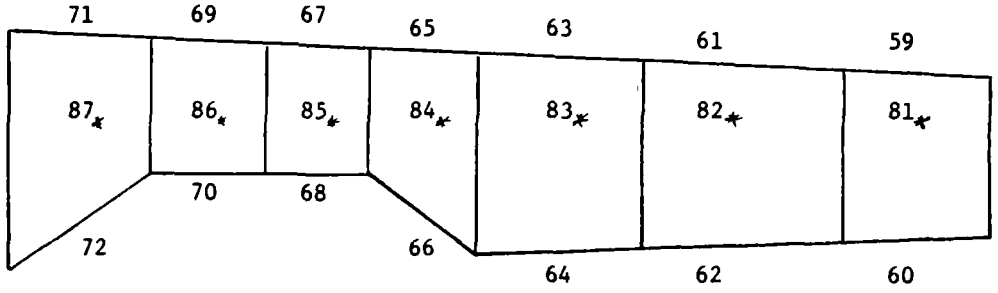
STRUCTURAL SIZING RIB NO. 1 (FWD)



Item	Panel* N°	Circular Arc Corrugations		
		θ°	R-In.	t-In.
Rib 1 (Fwd) Shear Webs	89	87	2.2	.056
	87	"	1.5	.041
	85	"	1.4	.031
	84	"	2.0	.030
	83	"	2.6	.063
	82	"	2.1	.027
	81	"	2.0	.020

Item	Bar	Area-In^2
Rib 1 (Fwd) Top Cap	71	.55
	69	.30
	67	.14
	65	.24
	63	.75
	61	.22
	59	.15
Rib 1 (Fwd) Bottom Cap	72	.55
	70	.30
	68	.14
	66	.24
	64	.75
	62	.22
	60	.15

J GARRISON	WING	FWD RIBS	V

ROOT RIB

BAY 1 — $\Theta = 87°$, $R = 20$, $t = .020$

FS 1730 - 1785
h = 56 h = 59

$D_L = 2\pi * 20 * \frac{87}{360} = 3.03$

$P_L = 2 * .9986 = 2.0$

$T_L = \frac{3.03}{2.0} = 1.52$

$A = (56+59)\frac{1}{2} * 55 * 1.52 = 4810\ in^2$

Ideal Wt = 4810 * .020 * .164 = 16 LB

BAY 2 — $\Theta = 87°$, $R = 2.1$, $t = .027$

FS 1640 - 1730
h = 62 h = 56

$T_L = 1.52$

$A = (62+56)\frac{1}{2} * 90 * 1.52 = 8070\ in^2$

Ideal Wt = 8070 * .027 * .164 = 36 LB

BAY 3 — $\Theta = 87°$ $R = 2.6$, $t = .063$

FS 1600 - 1640
h = 74 h = 62

$T_L = 1.52$

$A = (74+62)\frac{1}{2} * 40 * 1.52 = 4130\ in^2$

Ideal Wt = 4130 * .063 * .164 = 43 LB

SUB TOTAL 95 LB

2/

BAY 4 $\Theta = 87°$, R = 2.0, t = .030

FS 1560 - 1600

h = 36 h = 74 T_L = 1.52

A = (36 + 74)½ * 40 * 1.52 = 3340 in²

Ideal Wt = 3340 * .030 * .164 = 16 LB

BAY 5 $\Theta = 87°$, R = 1.4, t = .031

FS 1515 - 1560

h = 38 h = 36 T_L = 1.52

A = (38 + 36)½ * 45 * 1.52 = 2530 in²

Ideal Wt = 2530 * .031 * .164 = 13 LB

BAY 6 $\Theta = 87°$, R = 1.5, t = .041

FS 1470 - 1515

h = 42 h = 38 T_L = 1.52

A = (42 + 38)½ * 45 * 1.52 = 2730 in²

Ideal Wt = 2730 * .041 * .164 = 18 LB

BAY 7 $\Theta = 87°$, R = 2.2, t = .056

FS 1425 - 1470

h = 82 h = 38 T_L = 1.52

A = (82 + 38)½ * 45 * 1.52 = 4100 in²

Ideal Wt = 4100 * .056 * .164 = 38 LB

SUB TOTAL = 85 LB

ROOT RIB CAPS

BAY	LUPR	LLWR	AUPR	ALWR	WTUPR	WT LWR
1	47	59	55	.55	4.1	5.2
2	04	44	30	.30	2.1	2.1
3	44	44	14	.14	1.0	1.0
4	51	66	.24	.24	2.0	2.5
5	53	53	.75	.75	6.4	6.4
6	88	88	.22	.22	3.1	3.1
7	56	56	.15	.15	1.3	1.3
					20.0	21.6

TOTAL = 42 LB/SIDE

SEE STRENGTH NOTE

WT= (180 + 42 + 222) 1.28 = 568 LB ITEM 44

J Gamerson

Wing Root rib forward of X 1795

origonal reported data on sizing produced weight = 222 lbs./rib

This should be corrected by adding 222 lbs./rib (per side)

correction accounts for flexible body effects on root rib - - - present wing analysis is based on rigid wing root ties.

6/5/71 [illegible]

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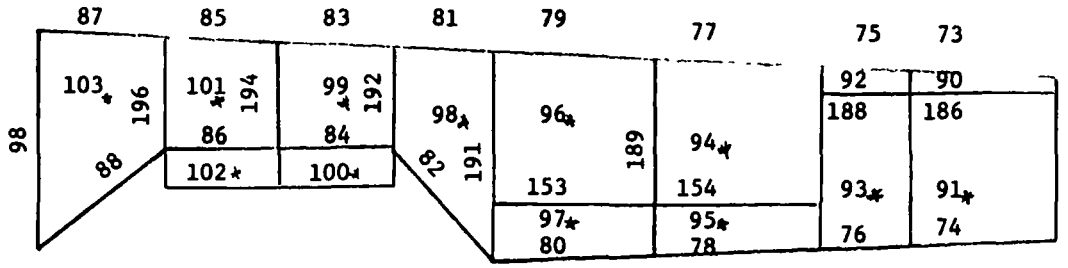
STRUCTURAL SIZING - RIB 2 (FWD)



Item	Panel*	Circular Arc Corrugation		
		θ°	R-In.	t-In.
Rib 2 (Fwd) Web	103	87	1.7	.029
	102	"	.44	.020
	101	"	.9	.025
	100	"	.4	.020
	99	"	.8	.020
	98	"	1.9	.036
	97	"	1.1	.037
	96	"	1.8	.051
	95	"	1.1	.039
	94	"	1.8	.053
	93	"	2.2	.043
	92	53	1.2	.055
	91	87	2.1	.036
	90	75	3.4	.020

Item	Bar	Area-In^2
Rib 2 (Fwd) Top Cap	87	.22
	85	.12
	83	.08
	81	.29
	79	.43
	77	.49
	75	.26
	73	.23

Item	Bar	Area-In^2
Rib 2 (Fwd) Bottom Cap	88	.22
	86	.14
	84	.08
	82	.29
	80	.21
	78	.24
	76	.42
	74	.32

J GARRISON	WING	FWD RIB	1

RIB 2 WEB

BAY 1 $\Theta = 87°$, R = 2.1 IN, t = 036

FS 1745 - 1785 $R = 2\pi * 2.1 * \frac{87}{360} = 3.19$

h = 65 h = 60 $R_L = 2.1 * .998 = 2.1$

$T_L = \frac{3.19}{2.1} = 1.52$

$A = (65+60)\frac{1}{2} * 45 * 1.52 = 4280 in^2$

IDEAL WT = 4280 * 036 * .164 = 25 LB

BAY 2 $\Theta = 87°$, R = 2.2, t = 043

FS 1710 - 1745

h = 70 h = 65 $T_L = 1.52$

$A = (65+70)\frac{1}{2} * 30 * 1.52 = 3080 in^2$

IDEAL WT = 3080 * 043 * .164 = 22 LB

BAY 3 $\Theta = 87°$, R = 18, t = 053

FS 1650 - 1710

h = 72 h = 70 $T_L = 1.52$

$A = (72+70)\frac{1}{2} * 60 * 1.52 = 6470 in^2$

IDEAL WT = 6470 * 053 * .164 = 56 LB

BAY 4 $\Theta = 87°$, R = 18, t = 051

FS 1600 - 1650

h = 78 h = 72 $T_L = 1.52$

$A = (78+72)\frac{1}{2} * 50 * 1.52 = 5700 in^2$

IDEAL WT = 5700 * 051 * .164 = 48 LB

SUB TOTAL 151 LB

2/

BAY 5 $\Theta = 87°$, R = 1.9, t = 036
FS 1560 - 1600
h: 20 h=18 T_L = 1.52

A = $(20+18)\frac{1}{2} * 40 * 1.52$ = 298 in²

IDEAL WT = 298 * 036 * .164 = 1.8 LB

BAY 6 $\Theta = 87°$, R = 8, t = 020
FS 1520 - 1560
h = 20 h = 20 t_L = 1.52

A = 20 * 40 * 1.52 = 1220 in²

IDEAL WT = 1220 * 020 * .164 = 4.0 LB

BAY 7 $\Theta = 87°$, R = .9 t = 025
FS 1470 - 1520
h = 25 h = 10 T_L = 1.52

A = $(10+25)\frac{1}{2} * 50 * 1.52$ = 1710 in²

IDEAL WT = 1710 * 025 * .164 = 7.0 LB

BAY 8 $\Theta = 87°$, R = 1.7, t = 024
FS 1425 - 1470
h = 73 h = 25 T_L = 1.52

A = $(73+25)\frac{1}{2} * 45 * 1.52$ = 3350 in²

IDEAL WT = 3350 * 029 * .164 = 19.0 LB

SUB TOTAL 48 LB

RIB 2 CAPS

BAY	L UPR	A UPR	WT UPR	L LWR	A LWR	WT LWR
	46	22	16	65	22	23
	44	.12	.8	44	.14	10
	44	08	.6	44	.108	.6
	51	29	24	75	.29	35
	53	43	37	53	.21	18
	57	49	45	57	.24	22
	31	26	1.3	31	42	21
	57	.23	21	57	32	29
			170 LB			164 LB

TOTAL = 33 LB / SIDE

TOTAL = (199 + 33) 1.28 = 297 LB ITEM 49

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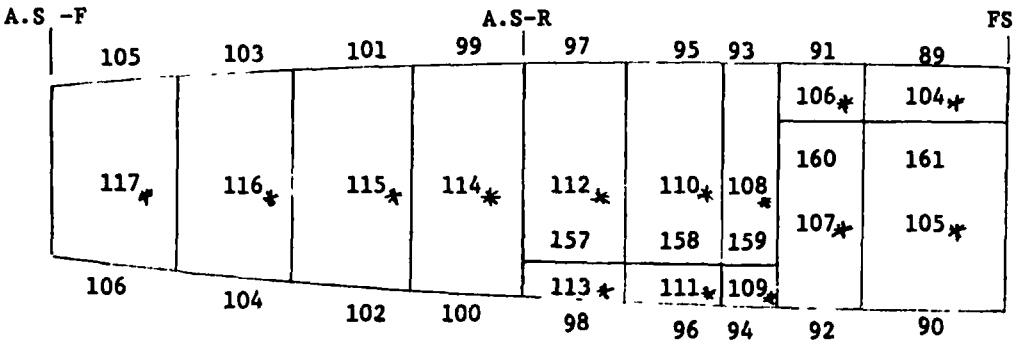
STRUCTURAL SIZING RIB 3 FORWARD



ITEM	PANEL *	CIRCULAR ARC CORRUGATION		
		θ°	$R_{IN.}$	$t_{IN.}$
RIB 3	117	87	2.0	.042
(FORWARD)	116	87	2.4	.047
WEB	115	87	2.6	.032
	114	87	2.7	.046
	113	87	.8	.026
	112	87	2.1	.050
	111	87	.8	.028
	110	87	2.1	.050
	109	87	.8	.026
	108	87	2.0	.052
	107	87	1.8	.026
	106	73	1.4	.057
	105	87	1.9	.045
	104	87	.8	.030

ITEM	BAR	AREA IN^2	ITEM	BAR	AREA IN^2
RIB 3	105	.37	RIB 3	106	.37
(FWD)	103	.49	(FWD)	104	.49
TOP	101	.30	BOTTOM	102	.30
CAP	99	.50	CAP	100	.50
	97	.47		98	.33
	95	.48		96	.54
	93	.48		94	1.37
	91	.45		92	1.27
	89	.14		90	.69

Y = 170
Y = 227 RIB 3 WEB ⌐ SINEWAVE WEB

BAY 1 Θ = 87° , R = 19 , t = 045

FS 1730 - 1785
h = 70" h = 65"

$P_L = 19 * .9986 = 19$
$D_L = 2\pi * 1.9 * \frac{87}{360} = 288$
$T_L = \frac{288}{1.9} = 1.52$

$A = (70+65)\frac{1}{2} * 55 * 1.52 = 5630_{IN^2}$

IDEAL WT = 5630 * 045 * .164 = 42 LB

BAY 2 Θ = 73°, R = 1.4, t = 057

FS 1700 - 1730
h = 72" h = 70"

$D_L = 2\pi * 1.4 * \frac{73}{360} = 1.78$
$P_L = 1.4 * .956 = 1.34$
$T_L = \frac{1.78}{1.34} = 1.34$

$A = (72+71)\frac{1}{2} * 30 * 1.34 = 2850_{IN^2}$

IDEAL WT = 2850 * 057 * 164 = 27 LB

BAY 3 Θ = 87°, R = 2.1, t = 050

FS 1645 - 1700
h = 75 h = 72

$D_L = 2\pi * 2.1 * \frac{87}{360} = 3.18$
$P_L = 2.1 * .9986 = 21$
$T_L = \frac{3.18}{2.1} = 1.52$

$A = (75+72)\frac{1}{2} * 55 * 1.52 = 6140_{IN^2}$

IDEAL WT = 6140 * 050 * .164 = 50 LB

BAY 4 Θ = 87°, R = 2.1, t = 050

FS 1600 - 1645
h = 76 h = 75

$D_L = 3.18$
$P_L = 2.1$
$T_L = 1.52$

$A = (75+76)\frac{1}{2} * 45 * 1.52 = 5160_{IN^2}$

IDEAL WT = 5160 * 050 * .164 = 42 LB

SUB TOTAL 161 LB

2/

Bay 5 $\Theta = 87°$, $R = 2.7"$, $t = .046$

FS 1550 - 1600 $D_L = 2\pi * 2.7 * \frac{87}{360} = 4.1$
h = 75 h = 76 $P_L = 2.7 * 9986 = 2.7$
$T_L = \frac{4.1}{2.7} = 1.52$

$A = (75+76)\frac{1}{2} * 50 * 1.52 = 5730_{IN^2}$

Ideal Wt = 5730 * 046 * .164 = 43 LB

Bay 6 $\Theta = 87°$, $R = 2.6$, $t = 032$

FS 1505 - 1550 $T_L = 1.52$
h = 70 h = 75

$A = (70+75)\frac{1}{2} * 45 * 1.52 = 4960_{IN^2}$

Ideal Wt = 4960 * 032 * .164 = 26 LB

Bay 7 $\Theta = 87°$, $R = 2.4$, $t = 047$

FS 1460 - 1505 $T_L = 1.52$
h = 55 h = 70

$A = (55+70)\frac{1}{2} * 45 * 1.52 = 4270_{IN^2}$

Ideal Wt = 4270 * 047 * .164 = 22 LB

Bay 8 $\Theta = 87°$, $R = 2.0$, $t = 042$

FS 1425 - 1460 $T_L = 1.52$
h = 53 h = 55

$A = (53+55)\frac{1}{2} * 35 * 1.52 = 2870_{IN^2}$

Ideal Wt = 2870 * 042 * 164 = 20 LB

Sub Total 111 LB

Total Ideal Web = 272 LB

RIB 3 CAPS

BAY	L_{UPR}	A_{UPR}	W_{UPR}	L_{LWR}	A_{LWR}	W_{LWR}
1	46	.37	2.7	47	.37	2.7
2	45	.49	3.5	45	.49	3.5
3	44	.30	2.1	44	.30	2.1
4	50	.50	4.0	50	.50	4.0
5	52	.47	3.9	52	.33	2.7
6	44	.48	3.4	44	.54	3.8
7	13	.48	1.0	13	1.37	2.9
8	31	.45	2.2	31	1.27	6.3
9	56	.14	1.3	56	.69	6.2
			24.1 LB			34.2 LB

TOTAL 56 LB/SIDE

BASIC WEB	272
DIAG WEB	161
TOTAL	433 LB/SIDE

BASIC CAPS	56
DIAG CAPS	22
TOTAL	78 LB/SIDE

$W_T = (433+78)\ 1.28 = 654$ LB ITEM 58

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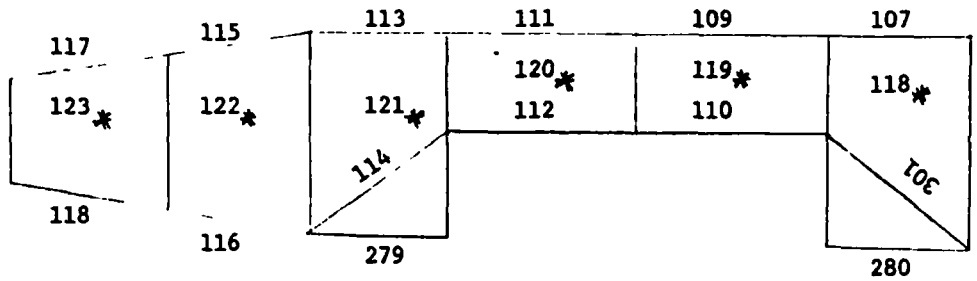
STRUCTURAL SIZING - RIB 4 (FORWARD)



ITEM	PANEL*	CIRCULAR ARC CORRUGATION		
		θ°	$R_{IN.}$	$t_{IN.}$
RIB 4 (FWD) WEB	123	87	1.4	.020
	122	87	2.1	.027
	121	87	1.4	.020
	120	87	.8	.020
	119	87	.8	.020
	118	87	1.5	.020

ITEM	BAR	AREA IN^2	ITEM	BAR	AREA IN^2
RIB 4 (FWD) TOP CAP	117	.11	RIB 4 (FWD) BOTTOM CAP	118	.11
	115	.22		116	.22
	113	.11		114	.11
	111	.08		112	.08
	109	.08		110	.08
	107	.12		108	.12

	Wing	Fwd Wing	Y

Rib 4 $\Theta = 87°$ $t_c = 1.52$

Bay	L_{upr}	A_{upr}	W_{upr}	L_{lwr}	A_{lwr}	W_{lwr}	Ap	t	Wt
1	46	11	8	46	.11	8	1715	020	8.4
2	50	22	1.8	50	22	1.8	2950	027	19.4
3	53	.11	.9	67	11	1.2	2240	020	10.9
4	44	08	.6	44	.08	.6	970	020	4.7
5	44	.08	.6	44	.08	.6	970	020	4.7
6	56	.12	1.1	75	.12	1.4	2360	020	12.0
			5.80			6.4 LB	11205 in²		60.1

Total Cap = 122 LB

Web 60.1 LB

Total 72 LB * 1.28 = 92 Item 66

Use this as unit wt basis for minor ribs

$A = \frac{11205}{144} = 77.8$ ft²

$Wt = \frac{72}{77.8} = .925$ psf Ideal

		Item
RIB 4A		
$\frac{185}{287} * 72 = 46 * 1.28 = 59$		71
RIB 5		
$\frac{185}{287} * 72 = 46 * 1.28 = 59$		76
RIB 5A		
$\frac{130}{287} * 72 = 18 * 1.28 = 23$		84
RIB 5B		
$\frac{30}{287} * 72 = 8 * 1.28 = 10$		89

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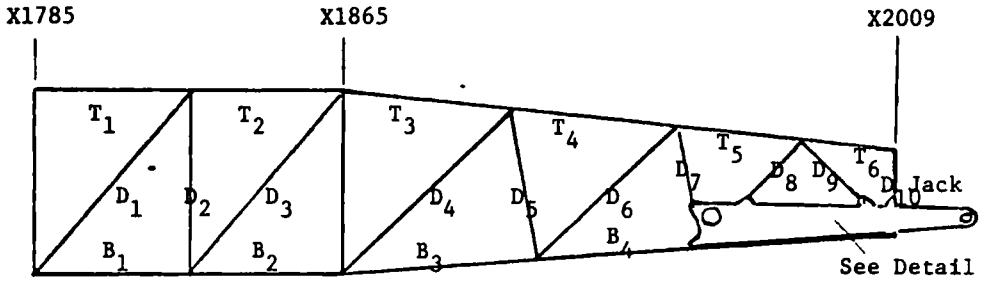
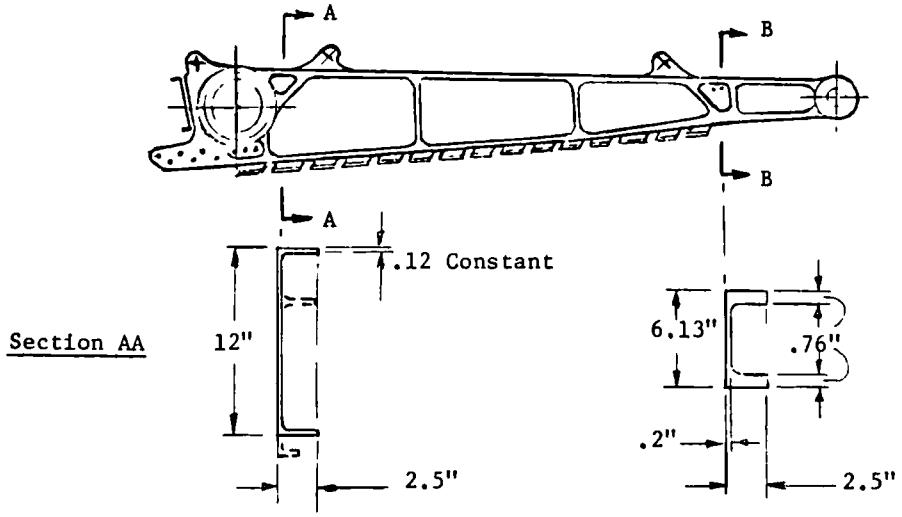
Wing Main Box - Elevon Drive Ribs 5 & 5A - Mat'l Ti 6-6-2 S.T.A.



Member	1	2	3	4	5	6	7	8	9	10
Diagonals D In^2	.25	.20	.25	.30	.25	.30	.30	.50	.94	.10
Top Cap T In^2	.20	.35	.45	.60	1.14	.50				
Bottom Cap B In^2	.20	.20	.30	.40						

Drive Rib Fitting/Elevon Hinge



Section AA

1/

ELEVON HINGE RIB

ELEMENT	L	X-SEC	WT	
TUBES				
D-1	62	.25	2.5	
D-2	65	.25	2.7	
D-3	61	.30	3.0	
D-4	55	.30	2.7	
D-5	40	.30	2.0	
D-6	52	.50	4.3	
D-7	42	.94	6.3	
~~V-1~~		~~.10~~		
V-2	51	.20	1.8	
~~V-3~~		~~.20~~		
V-4	45	.25	1.8	
~~V-5~~		~~.10~~		
		Σ	27.1	LB/SIDE

END FTG .42 × 27.1 = 11.4 LB/SIDE

CAPS

L	A_U	A_L	W_U	W_L
40	.2	.2	1.3	1.3
40	.35	.2	2.3	1.3
38	.45	.3	2.8	1.9
38	.6	.4	3.8	2.5
42	1.14		7.9	
27	.5		2.2	
		Σ	20.3	7.0

TOTAL 27.3 LB/SIDE

2/

HINGE/DRIVE FTG

$1.5 * \frac{1}{2} [17.8 * .12 + (6.13 * .2 + 5 * .16)] 63 * .164 = 55$ LB

TOTAL = 121 LB LB/SIOG * 1.28 = 154

ITEMS 78 & 81

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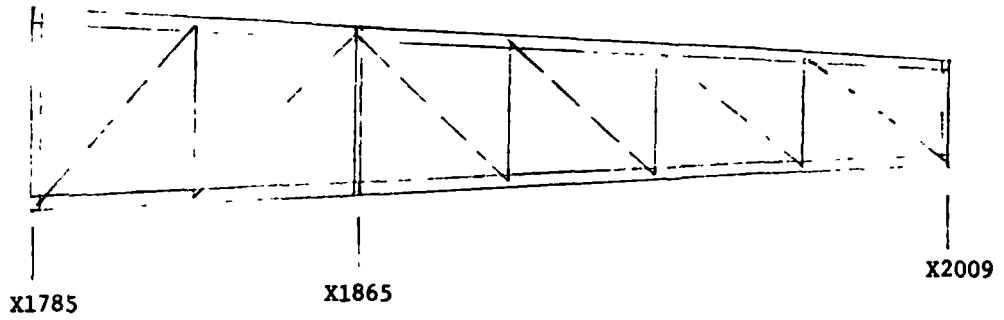
TYPICAL INTERMEDIATE RIB
RIB 3A - TRUSS WEB DESIGN



Item	Weight (lb)
Cap Members	17.25
Vertical Truss Members	5.35
Diagonal Truss Members	6.80
Total Weight	29.4

Material: Ti-6AL-6V-2Sn for cap channel members
Ti-6AL-4V for truss tubes

RIB 3A

IDEAL WT 27.7 LB

FTG 42% = 11.7 LB

SUB TOTAL = 39.4 LB

NON OPT 28% 11 LB

50 LB

USE THIS AS BASIS FOR TYPICAL INTERMEDIATE RIBS

			Item
2 A	50	LB/SIDE	52
2 B	75		55
3	50		60
3 A	50		63
4	50		68
4 A	50		73
5 B	45		86
5 C	40		91
5 D	35		94
6	30		97
INBD ACS	38		100
OUTBD "	20		103

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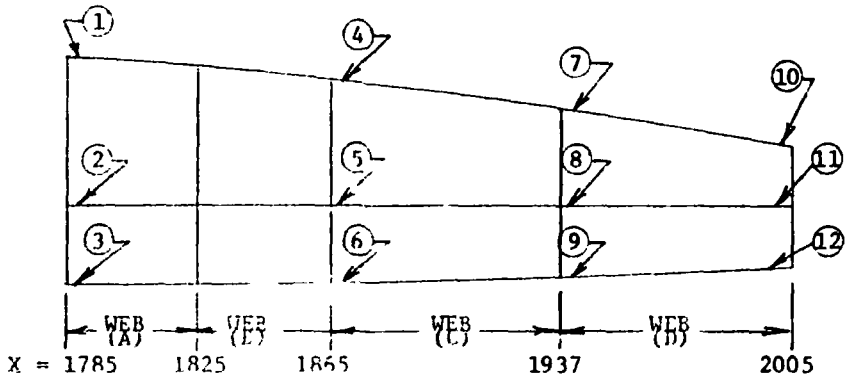
WING CARRYTHROUGH

RIB CAP AREAS AND PANEL THICKNESSES



CAP LOCATION	CAP AREAS RIB LOCATION				
	Y = 0	Y = 27.7"	Y = 55.4"	Y = 84.74"	Y = 119"
(1)	.24"^{2}	.06"^{2}	.06"^{2}	.06"^{2}	.06"^{2}
(2)	.56	.30	---	.30	.36
(3)	.30	.06	.24	.06	.06
(4)	.19	.11	.97	.06	.09
(5)	.30	.14	---	.14	.10
(6)	.17	.12	.12	.09	.09
(7)	.14	.09	.08	.08	.14
(8)	.10	.10	---	.10	.10
(9)	.06	.06	.14	.08	.07
(10)	.06	.06	.07	.08	.14
(11)	.10	.10	.10	.10	.10
(12)	.06	.06	.06	.06	.06
WEB	WEB THICKNESS ($\bar{t}$)				
A	.041"	.033"	.038"	.035"	.035"
B	.036	.033	.039	.033	.033
C	.036	.033	.033	.033	.033
D	.033	.033	.033	.038	.047

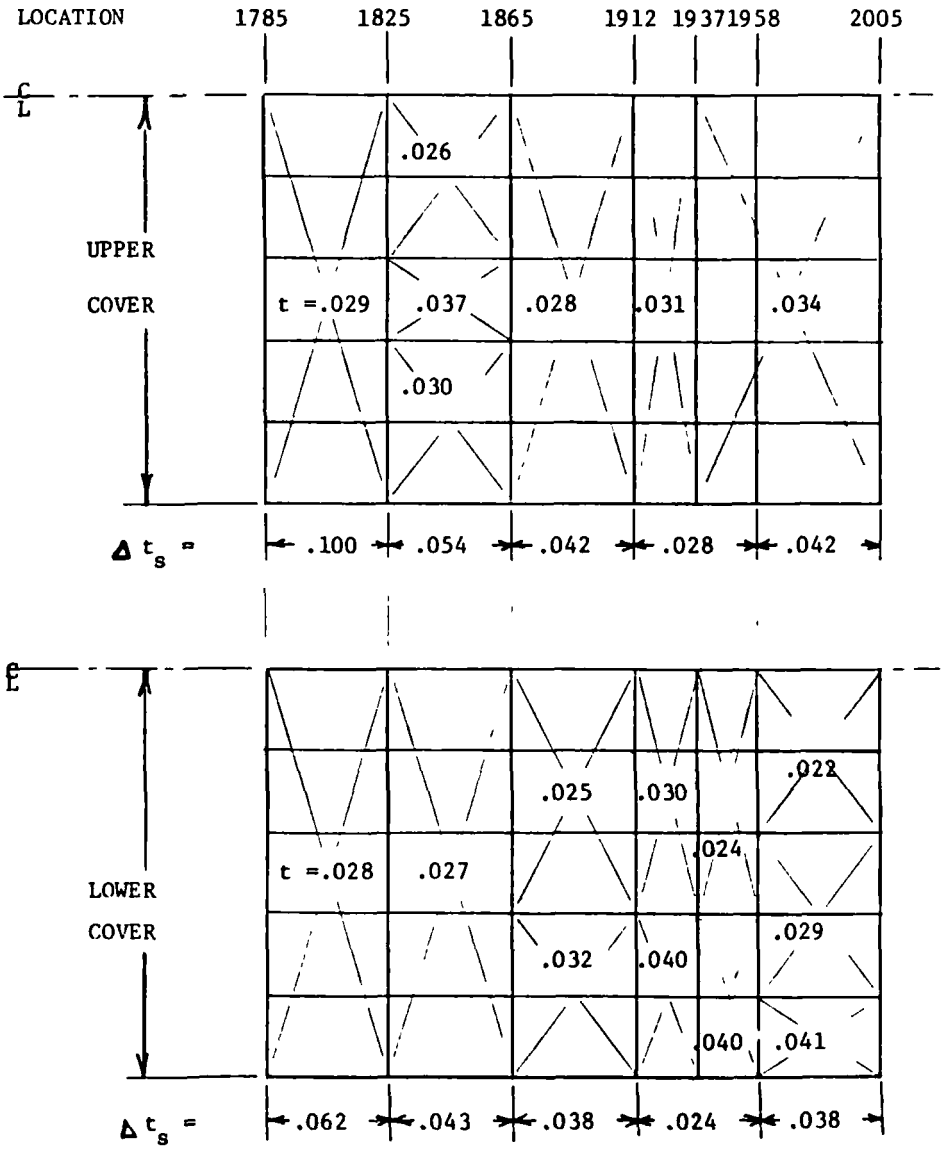
MATERIAL. Ti-6Al-6V-2Sn TITANIUM ALLOY

WING CARRYTHROUGH

UPPER AND LOWER COVER THICKNESSES

NOTE:

1. MATERIAL: SKIN = TITANIUM (Ti-6AL-6V-2Sn)
   STRINGERS = BORON-ALUMINUM
2. t_s = SKIN THICKNESS IN INCHES
3. Δt_s = STRINGER EQUIVALENT THICKNESS IN INCHES
4. $\bar{t} = t_s + \Delta t_s$ = SMEARED THICKNESS



J GARRISON	WING	CARRY THRU	V

SKIN - MATERIAL 6-6-2 t
STRINGERS - MATERIAL - BORON - ALUMINUM

Upper Cover

Bay 1 $(160+157)\frac{1}{2} * 40 * 029 * .164$ = 302 LB

$(160+157)\frac{1}{2} * 40 * .100 * 095$ = 60.4 LB

30.6 LB/SIDE

Bay 2 $55.4 * 40 * 026 * 164$ = 9.5 LB
$29.34 * 40 * 037 * .164$ = 7.1 LB
$(77.26+70.26)\frac{1}{2} * 40 * 330 * .164$ = 15.0 LB

$(157+155)\frac{1}{2} * 40 * 054 * 095$ = 32.0 LB

63.6 LB/SIDE

Bay 3 $(155+152)\frac{1}{2} * 47 * 028 * 164$ = 33.1 LB

$(155+157)\frac{1}{2} * 47 * 092 * 095$ = 29.4 LB

62.5 LB/SIDE

Bay 4 $(152+150)\frac{1}{2} * 25 * 031 * .164$ = 19.2 LB

$(152+150)\frac{1}{2} * 25 * 028 * 095$ = 10.0 LB

29.2 LB/SIDE

Bay 5 $(150+145)\frac{1}{2} * 72 * 034 * .164$ = 59.2 LB

$(150+148)\frac{1}{2} * 21 * 078 * 095$ = 23 LB
$(148+145)\frac{1}{2} * 51 * 042 * 095$ = 29.9 LB

97.4 LB/SIDE

Upper Cover = 343.3 LB/SIDE Ideal

SKIN 1733 * 128 = 222 LB/SIDE ITEMS 108
STR'R 1701 * 128 = 218 LB/SIDE 113

Lower Cover

Bay 1	Skin	$(160+157)\frac{1}{2} * 40 * 028 * .164$	=	292 LB
	Stgr	$(160+157)\frac{1}{2} * 40 * 062 * 095$	=	375 LB
				667 LB/SIDE
Bay 2	Skin	$(157+155)\frac{1}{2} * 40 * 027 * .164$	=	27.6 LB
	Stgr	$(157+155)\frac{1}{2} * 40 * 043 * 095$	=	25.5 LB
				53.1 LB/SIDE
Bay 3	Skin	$84.7 * 47 * 025 * .164$	=	163 LB
		$(70.3+67.3)\frac{1}{2} * 47 * 032 * .164$	=	36.1 LB
	Stgr	$(155+152)\frac{1}{2} * 47 * 038 * 095$	=	26.0 LB
				784 LB/SIDE
Bay 4	Skin	$84.7 * 25 * 030 * .164$	=	10.4 LB
		$(67.3+65.3)\frac{1}{2} * 040 * 475 * .164$	=	27.2 LB
	Stgr	$(152+150)\frac{1}{2} * 024 * 25 * 095$	=	9.3 LB
				46.9 LB/SIDE
Bay 5	Skin	$84.7 * 21 * 024 * 164$	=	7.0 LB
		$(65.3+63.3)\frac{1}{2} * 040 * 21 * .164$	=	8.9 LB
	Stgr	$(150+148)\frac{1}{2} * 21 * 024 * .095$	=	7.1 LB
				23.0 LB/SIDE
Bay 6	Skin	$55.4 * 51 * 022 * .164$	=	10.2 LB
		$63.6 * 51 * 029 * .164$	=	15.4 LB
		$(29+26)\frac{1}{2} * 51 * 041 * .164$	=	9.4 LB
	Stgr	$(148+145)\frac{1}{2} * 51 * 038 * 095$	=	26.9 LB
				61.9 LB/SIDE

Lwr Cover — 330 ~ LB/SIDE

Skin 197.7 * 1.28 ~ 253 LB/SIDE — Item 110

Stgr 132.3 * 1.28 = 170 LB/SIDE — 115

3/

RIBS

MATERIAL 6-6-2 Ti

BL 0

UPR CAP

81 (.43 + .19) ½ * .164 = 4.1 LB
71 (.19 + .14) ½ * .164 = 1.9 LB
75 (.14 + 06) ½ * .164 = 1.2 LB

MID CAP

80 (.56 + .30) ½ * .164 = 5.3 LB
71 (30 + 10) ½ * .164 = 2.3 LB
75 (.10 + 10) ½ * 164 = 1 2 LB

LWR CAP

81 (.30+ 17) ½ * .164 = 3.1 LB
71 (17 + 06) ½ * .164 = 1 3 LB
75(06 + 06) ½ * .164 = .7 LB

WEB A

40*68 * 041 * .164 = 18 3 LB

WEB B

40 * 65 * 036 * 164 = 15.5 LB

WEB C

72 * 56 * 036 * .164 = 23 8 LB

WEB D

74 * 44 * 523 * .164 = 17 6 LB

CAPS	21.8 LB
• WEBS	75.2 LB
	96.3 * 1.28 = 123 LB

Item 119

4/

BL 27.7

Upr Cap

81 (06 + 11) $\frac{1}{2}$ * .164 = 1.1 LB
71 (.11 + 09) $\frac{1}{2}$ * .164 = 1.2 LB
75 (.09 + 06) $\frac{1}{2}$ * .164 = 9 LB

Mid Cap

80 (30+14) $\frac{1}{2}$ * .164 = 2.9 LB
71 (.14 + 10) $\frac{1}{2}$ * 164 = 1.4 LB
75 (10+ 10) $\frac{1}{2}$ * .164 = 1.2 LB

Lwr Cap

81 (06+ 12) $\frac{1}{2}$ * 164 = 1.2 LB
71 (12+.06) $\frac{1}{2}$ * .164 = 1.0 LB
75 (06+ 06) $\frac{1}{2}$ * 164 = 7 LB

Web A

40 x 68 x 033 x .164 = 14.7 LB

Web B

40 x 63 x 033 x .164 = 14.2 LB

Web C

72 x 56 x 033 x .164 = 21.8 LB

Web D

74 x 44 x 033 x .164 = 17.6 LB

Caps	11.6 LB
Web	68.3 LB
	79.9 * 1.28 = 105 LB

ITEM 121

5/

BL 55.4

Upr CAP

81 (06+.97) $\frac{1}{2}$ * 164 = 69 LB
71 (97 + 08) $\frac{1}{2}$ * 164 = 61 LB
75 (08 + .07) $\frac{1}{2}$ * 164 = 9 LB

Lwr CAP

81 (.24 + 12) $\frac{1}{2}$ * .164 = 2.4 LB
71 (.12 + 14) $\frac{1}{2}$ * 164 = 1.5 LB
75 (.14 + .06) $\frac{1}{2}$ * .164 = 1.2 LB

Web A

40 x 68 * 039 * .164 = 16.9 LB

Web B

40 x 65 * 039 * .164 = 16.7 LB

Web C

72 x 56 * 033 * .164 = 21.8 LB

Web D

74 x 44 * 033 * .164 = 17.6 LB

CAPS 19.0 LB
WEBS 73.0 LB

92.0 * 1.28 = 118 LB ITEM 124

6/

BL 84.74

Upr Cap

81 (06 + 06) ½ * 164 = 8 LB
71 (06 + .08) ½ * .164 = .8 LB
75 (08 + 08) ½ * .164 = 1.0 LB

Mid Cap

80 (.30 + .14) ½ * .164 = 2.9 LB
71 (14 + .10) ½ * 164 = 1.4 LB
75 (10 + .10) ½ * .164 = 1.2 LB

Lwr Cap

81 (06 + 09) ½ * 164 = 1.0 LB
71 (09 + 08) ½ * .164 = 1.0 LB
75 (08 + 06) ½ * .164 = .9 LB

Web A

40 x 68 * 035 * .164 = 15.6 LB

Web B

40 x 65 * 033 * .164 = 14.1 LB

Web C

72 x 56 * 033 * .164 = 21.8 LB

Web D

74 x 44 * 038 * .164 = 20.3 LB

Caps 11.0 LB
Web 71.8 LB

82.8 * 1.28 = 106 LB Item 127

7/

BL 119

UPR CAP

81 (.06+09) ½ * .164 = 1.0 LB
71 (.09 + 12) ½ * .164 = 1.3 LB
75 (.12 + .12) ½ * .164 = 1.7 LB

MID CAP

80 (.36+.10) ½ * .164 = 3.0 LB
71 (.10 + .10) ½ * .164 = 1.2 LB
75 (.10 + 10) ½ * .164 = 1.2 LB

LWR CAP

81 (.06+09) ½ * .164 = 1.0 LB
71 (09 + 07) ½ * .164 = .9 LB
75 (.07+ 06) ½ * .164 = .8 LB

WEB A

40 * 68 * 035 * .164 = 15.6 LB

WEB B

40 * 65 * 033 * 164 = 14.1 LB

WEB C

72 * 56 * 033 * .164 = 21.8 LB

WEB D

74 * 44 * 047 * 164 = 25.1 LB

CAPS	12.1 LB
WEB	76.6 LB
	88.7 * 1.28 = 114 LB

ITEM 130

SECONDARY STRUCTURE

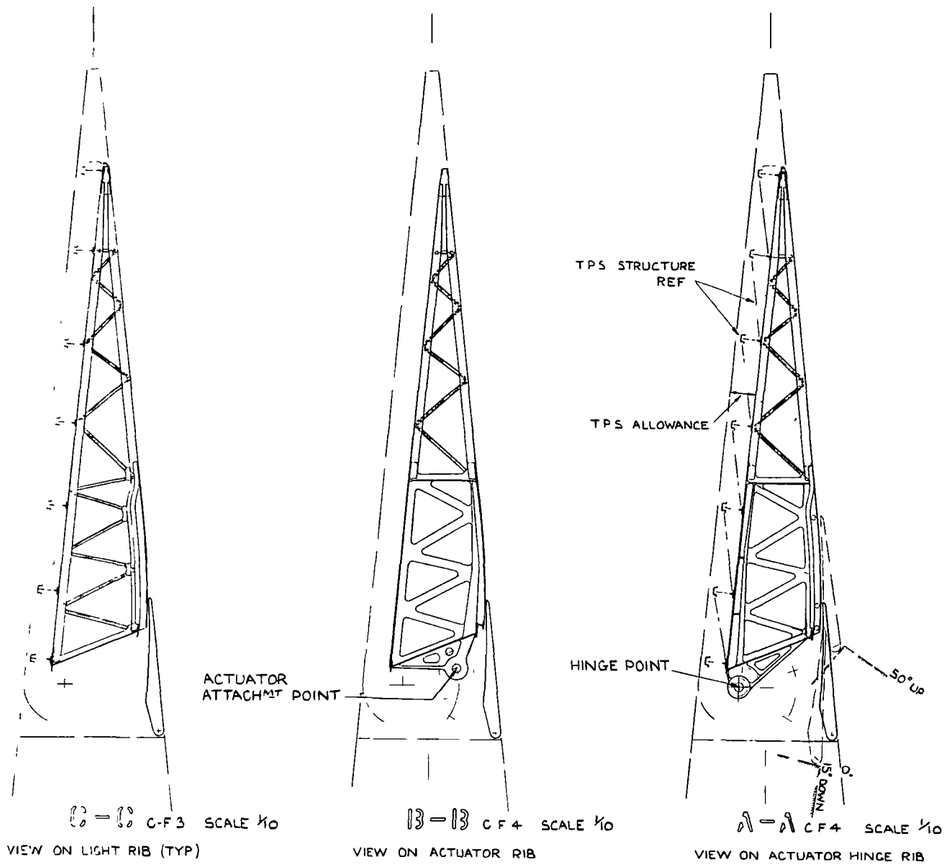
DOORS - USE MAC 747 EMPERICAL CORRELATION

WT = .43 (Δ PRESS - PSF)$^{.3}$ * AREA

DOOR INCREMENT (MAC 747) INCLUDES ACTUATION

AREAS FROM SUBSYSTEMS

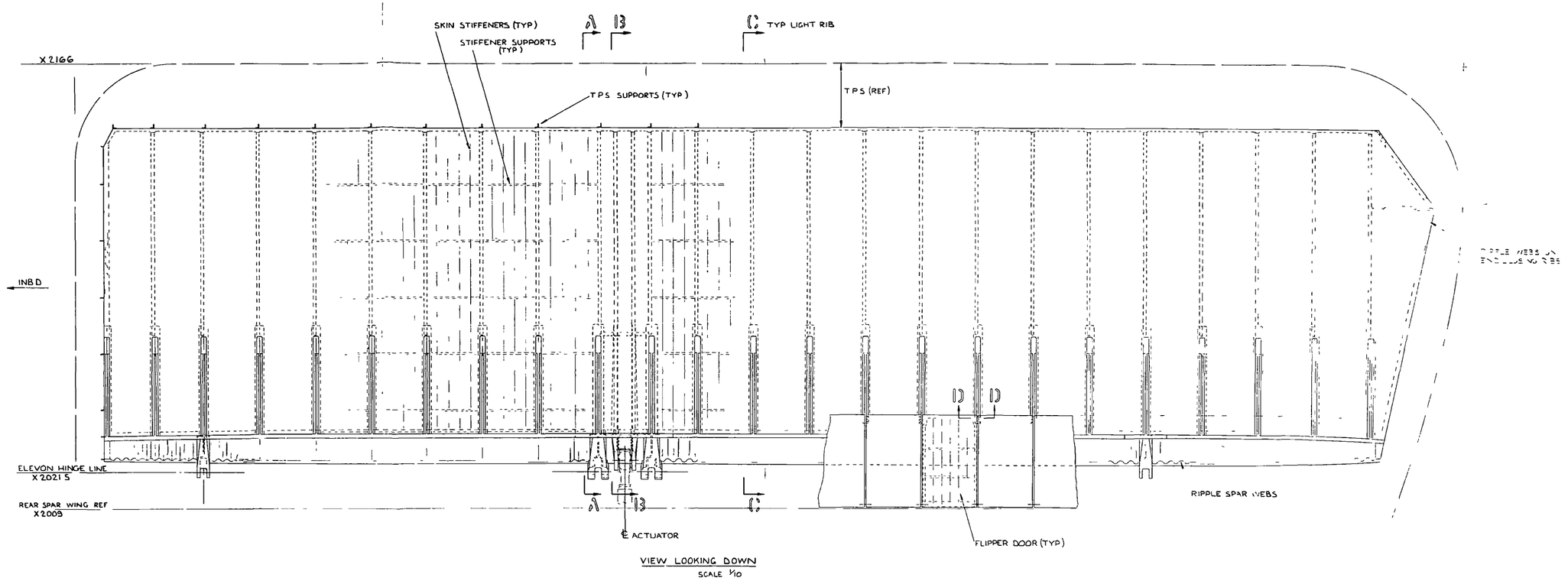
					ITEM
MLG	.43 (700)$^{.3}$ * 845	=	259	LB/SIDE	142
ABES FWD	.43 (700)$^{.3}$ 146	=	442	LB/SIDE	145
ABES APT	.43 (700)$^{.3}$ 146	=	442	LB/SIDE	147



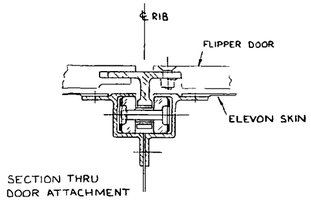
VIEW ON LIGHT RIB (TYP)

VIEW ON ACTUATOR RIB

VIEW ON ACTUATOR HINGE RIB



VIEW LOOKING DOWN
SCALE 1/10



SECTION THRU DOOR ATTACHMENT
(TYP)
SCALE 1/1

2.1-111 Continued

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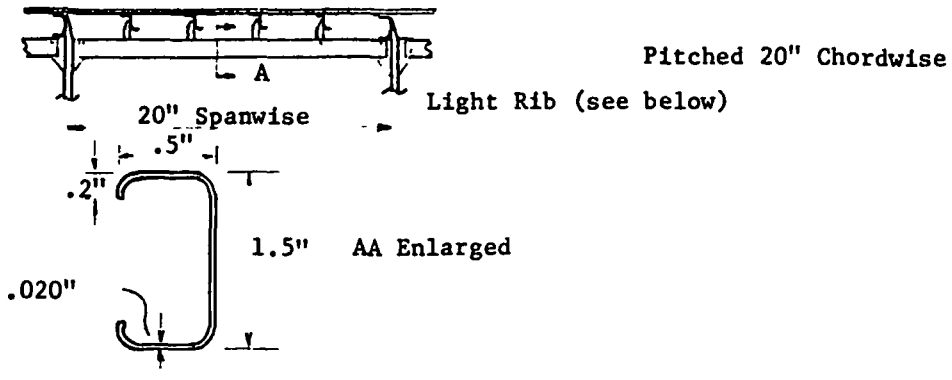
Elevon Sizing Summary

Y Station In.	F/S Web			F/S Cap Area		Cover Skin In.
	Depth In.	Gage In.	R - In.	Top In^2	Bottom In^2	
146	10.0	.020	.74	.057	.057	.030
184	16.3	.020 .024	.74	.057	.057	.030
240	19.5	.020	.74	.090	.100	.030
291	21.8	.020	.74	.063	.080	.031
341	22.5	.020 .040	.74 .96	.142	.157	.034 .039
401	20.5	.035	.96	.168	.152	.042
461	20.4	.033	.96	.351	.317	.043
511	19.4	.035 .020	.96 .74	.570	.517	.039 .036
550	17.6	.020	.74	.285	.258	.033
600	15.9	.020	.74	.057	.057	.030
630		.020	.74	.057	.057	.030

*

* Add 40% to skins for stiffeners
Note - F/S web & caps - Ti-6AL-4V annealed
Cover skins - Ti-6AL-62-$2S_N$ S.T.A.
T/E Member - Same gage as skins - channel section

Stringer Support Members - Mat'l Ti-6AL-6V-2Sn S.T.A.



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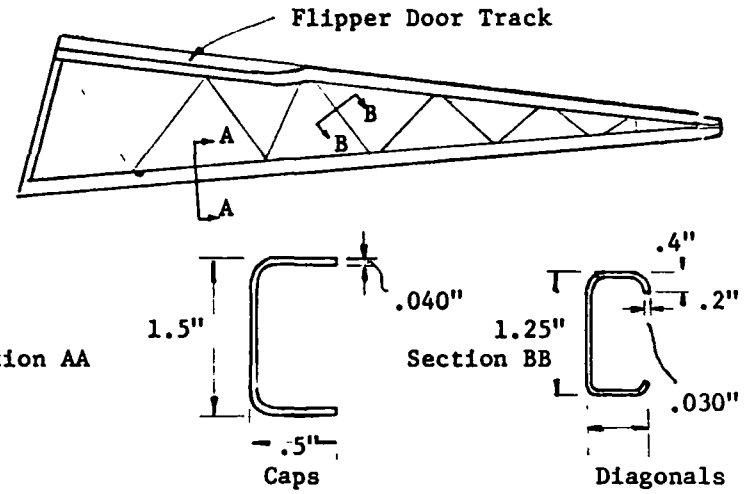
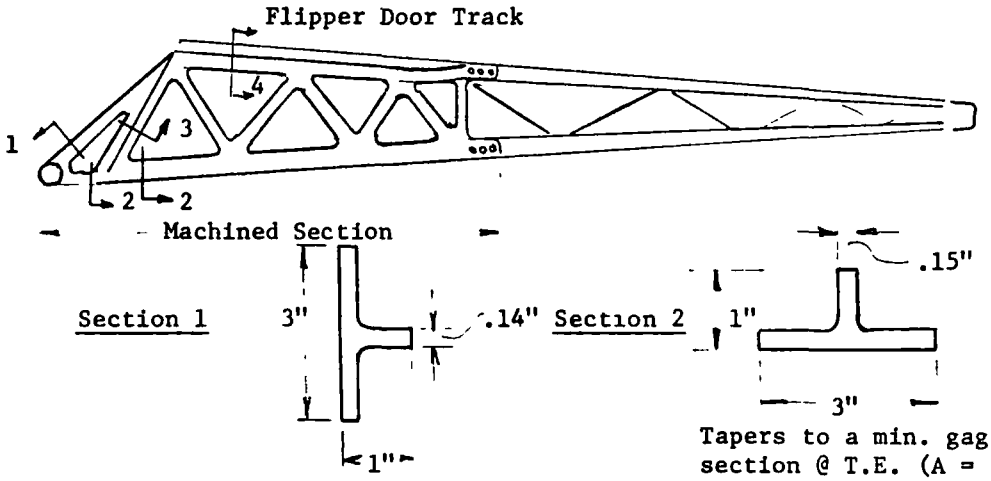
Light Ribs - Mat'l Ti-6-6-2 S.T.A.



O/B Hinge Rib - Mat'l Ti 6-6-2 S.T.A.



Section 3 As Section 1.

Section 4 Area = .80 in^2; to min section @ T.E.

I/B Hinge Rib - Mat'l Ti 6-6-2

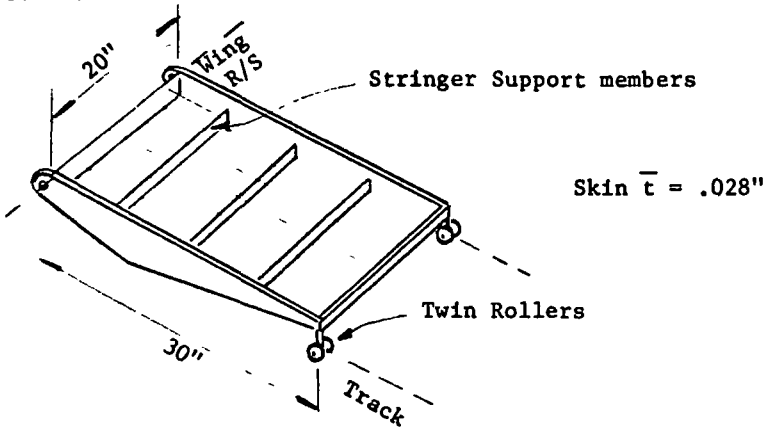
Front sections 50% of O/B hinge, tapering to minimum gage sections @ T.E.

Drive/Center Hinge Ribs - Mat'l Ti 6-6-2

1) Drive Ribs (2)
   Top Cap 2.09 in^2 @ F/S to 0.05 in^2 @ T.E.
   Bottom Cap 0.2 in^2 @ F/S to 0.05 in^2 @ T.E.

2) Hinge Ribs (2)
Sections same as for O/B hinge rib except bottom cap which tapers from 1.89 in^2 at F/S to min. gage section @ T.E.

Flipper Doors - Skinned only on top, Mat'l Ti 6-6-2 S.T.A.



Stringer Support Member (4)	Channel	-1.25" Deep, .4" flanges .2" lips in .020" gage @ 7" pitch
Side Members (2)	Channel	Flange width - .8", gage .08"
T.E. Member	Channel	1.25", .5" flanges .040" gage

ELEVON SUMMARY

UPR COVER			446 LB
SKIN		327	
STG'R		119	
LWR COVER			454 LB
SKIN		324	
STG'R		130	
FRONT SPAR			96 LB
CAPS		29	
WEB		67	
INT RIB			133 LB
	19 @	7	
HINGE RIB			46 LB
	2 @	23	
DRIVE RIBS			144 LB
	4 @	36	
INTER COSTALS			23 LB
FLIPPER DOORS			
	23 @	7	161 LB
HINGES			80 LB
SUB TOTAL			1580 LB/SIDE
NON OPTIMUM	15%		237 LB
			1817 LB/SIDE

ELEVON 1/

UPR SKIN 6-6-2 t.

BAY	W	L	t	WT
1	110	135	030	73 LB
2	110	25	031	14 LB
3	110	25	034	15 LB
4	110	30	039	21 LB
5	110	60	042	45 LB
6	110	55	043	44 LB
7	110	45	039	32 LB
8	110	40	033	24 LB
9	110	53	030	29 LB

SUB TOTAL 297 LB

			Item
ADD 10% FOR CSK PADS	30 LB	327 * 1.15 = 376 LB	151
ADD 40% FOR STG'R	119 LB	119 * 1.15 = 136 LB	156

TOTAL UPR COVER 446 LB/SIDE

2/

LWR SKIN 6-6-2 TI

BAY	W	L	t	WT
1	120	135	030	80
2	120	25	031	15
3	120	25	034	16
4	120	30	039	23
5	120	60	042	49
6	120	55	043	48
7	120	45	039	35
8	120	40	033	26
9	120	53	030	32

					It = mm
SUB TOTAL	324 LB	* 1.15	=	372 LB	153
ADD 40% FOR STG'R	130 LB	* 1.15	=	149 LB	159

TOTAL LWR COVER 454 LB / SIDE

3/

FRONT SPAR 6-6-2 TL

WEB $\Theta = 77.5$ $T_L = \frac{2\pi \frac{\Theta}{360}}{\sin\Theta} = \frac{2\pi}{.976}\frac{.775}{360} = 1.394$

BAY	L	h	t	WT
1	185	24	020	20 LB
2	60	24	040	13 LB
3	60	24	035	12 LB
4	50	24	039	10 LB
5	113	24	020	12 LB

TOTAL 67 LB/SIDE

CAPS - UPR

BAY	L	A_1	A_2	WT
1	28	057	057	.3
2	57	057	090	.7
3	51	090	063	.6
4	50	063	.142	.8
5	60	.142	.168	1.5
6	60	.168	.351	2.6
7	50	.351	.570	3.8
8	40	.570	.285	2.8
9	50	.285	.057	1.4
10	14	.057	.057	.1

TOTAL 14.6 LB/SIDE

4/

CAPS - LWR

BAY	L	A_1	A_2	WT
1	28	057	057	3
2	57	057	.100	.7
3	51	100	080	.8
4	50	080	.157	1.0
5	60	.157	.152	1.5
6	60	152	317	2.3
7	50	317	517	3.4
8	40	517	.258	2.3
9	50	.258	057	1.3
10	14	057	057	.1

TOTAL 13.9 LB/SIDE

Σ 96 * 1.15 = 110 LB ITEM 162

FLIPPER DOORS

UPR COVER

20 * 33 * 028 * .164 = 3.0 LB

CROSS MEMBERS

20 * 2.45 * 020 * 164 * 4 = .6 LB

SIDE MEMBERS

33 * 3 * 080 * .164 * 2 = 2.6 LB

TRAILING EDGE

20 * 2.5 * 040 * .164 = .3 LB

SUB TOTAL 6.5 LB/DOOR

HINGES & ROLLERS 5 LB

TOTAL 7.0 LB/DOOR

7 * 23 * 1.15 = 185 LB ITEM 171

STRINGER SUPPORT MEMBERS

2.9 * 020 * 20 * .164 = .2 LB EACH

5 REQ'D CHORDWISE, 23 BAYS

WT = .2 * 5 * 23 = 23 LB/SIDE * 1.15 = 26 ITEM 169

INTERMEDIATE RIBS

CAPS 110 UPR +120 LWR

2.5 * 040 * 230 * .164 = 3.8 LB

TRACK

40 * 25 * .164 = 1.6 LB

STRUTS

X-SEC = 2.05 * 020 = 050

TOTAL LENGTH = 190 IN

WT = 190 * 050 * .164 = 1.6 LB

TOTAL = 7.0 LB EACH

HINGE RIB

UPR CAP

(4 * .15 + .1) ½ * 110 * .164 = 6.3 LB

LWR CAP

(4 * 15 + .1) ½ * 120 * .164 = 6.9 LB

STRUTS

(.6 + .05) ½ * 190 * .164 = 10.1 LB

TOTAL 23.3 LB

DRIVE RIB

UPR CAP (SAME AS HINGE) = 6.3 LB

LWR CAP

$(1.89 + .05)\frac{1}{2} * 120 * 164$ = 19.1 LB

STRUTS 10 LB

TOTAL 35.5 LB

HINGES

20 * .1 = 20
20 * .1 = 20
$3 * \frac{\pi}{4} 5^2$ = 70
$60 in^3 * .164 = 10$ LB/HALF

4 REQ'D $4 * 10 * 2 = 80$ LB $* 1.15 = 92$ LB ITEM 14

RIB TOTAL

1907 = 133 * 1.15
2023 = 46 * 1.15
4036 = 100 * 1.15

371 LB ITEM 165

NON OPTIMUM

GAGE TOLERANCE	5%
FASTENERS	10%

Detail Weight Statement

(Tail Group)

Item	Weight	Page No.
Tail Group	[5104]	
Basic Structure		
Torque Box	[2649]	2.2-11
Covering	(1238)	2.2-14
Skin	743	
Stringers	495	
Front Spar	(266)	2.2-14
Caps	203	
Web	63	
Mid Spar	(300)	2.2-15
Caps	220	
Web	80	
Rear Spar	(229)	2.2-15
Caps	172	
Web	57	
Ribs	(1411)	2.2-16-19
Hinge Ribs (2)	54	
Drive Ribs (2)	60	
Intermediate (15)	337	
Cap Rib (1)	18	
Leading Edge	[731]	2.4-5
Carbon-Carbon	(422)	
Attachment	(107)	
Insulation	(202)	
Control Surfaces		
Rudder	[1260]	2.2-20
Covering	(885)	2.2-22
Skin	522	
Stringers	351	
Close-out	12	
Front Spar	(87)	2.2-22
Caps	35	
Web	52	
Ribs	(192)	
Intermediate (13)	109	2.2-22-24
Drive (2)	42	
Hinge (2)	16	
Cap (2)	25	
Hinge Fittings	(96)	2.2-20
Contingency	[464]	2.2-3

DETAILED WEIGHT SUBSTANTIATION
TAIL GROUP

2. TAIL GROUP	VERTICAL			5104
BASIC STRUCTURE	(3480)	( )	3480	
TORQUE BOX	2649			
CARRY THROUGH				
LEADING EDGE	731			
TRAILING EDGE	N/A			
SECONDARY STRUCTURE	N/A			
CONTROL SURFACES	SURFACE	SUPT/MECH	1260	
RUDDER (INCL. BAL WT_____LB)	1260	INC'L		
CONTINGENCY			464	

THE VERTICAL TAIL ON THE ANALYSIS VEHICLE IS CONSIDERED "HOT STRUCTURE" AND CONSEQUENTLY IS CONSTRUCTED OF INCONEL-718 MATERIAL WITH GEOMETRY DEFINED BY THE VERTICAL TAIL- STRUCTURAL ASSEMBLY DRAWING 255BJ23059.

THE STRENGTH REQUIRED GAGES AND CROSS SECTIONAL AREAS ARE DEFINED IN REPORT NO. E0308, SECTION 2.3.1.3 FOR THE EXTERNAL LOADS DEFINED IN REPORT NO. E0308, SECTION 2.2.6.2. FOR CONVENIENCE THESE GAGES AND AREAS ARE DUPLICATED WITH THE APPLICABLE CALCULATION.

THE VERTICAL TAIL WEIGHTS AND INERTIAS ARE SUMMARIZED ON PAGES 2.2-4 AND 2.2-5 WITH THE FOLLOWING 3 PAGES BEING THE DETAIL MASS PROPERTIES COMPUTER INPUT FOR WEIGHT, CG, AND MOMENT OF INERTIA.

IN GENERAL THE TAIL WEIGHT IS 80% DETAIL WEIGHT CALCULATION FROM STRENGTH SUPPLIED DATA WITH APPROXIMATELY 20%, BY WEIGHT, ALLOWANCES FOR SPLICES, FASTENERS, AND MISCELLANEOUS.

THE LEADING EDGE WEIGHTS (AS WITH THE WING) ARE CARRIED IN THE TAIL SECTION FOR SUMMARIZING PURPOSES, WITH THE DETAIL CALCULATIONS IN THE THERMAL PROTECTION SECTION (2.4-5).

AS NOTED IN THE INTRODUCTION, SECTION 1.0, THE WEIGHT CONTINGENCY HAS A VARIATION FROM 28% ON CONCEPTUAL WORK TO 15% FOR LAY-OUT WORK TO 5% ON CALCULATIONS OF DETAIL DRAWINGS. THE STRUCTURAL WEIGHT ANALYSIS PRESENTED ON THE FOLLOWING PAGES IS FURTHER ADVANCED THAN THE LAYOUT PHASE BUT DOES NOT HAVE THE DEPTH REQUIRED FOR DETAIL DRAWING CALCULATIONS. CONSEQUENTLY A CONTINGENCY OF 10% IS APPLIED TO ALL STRUCTURAL SUBSYSTEMS.

MASS PROPERTIES SUMMARY 06/09/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y (INCH)	Z (INCH)	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
					(SLUG-FEET SQ./1000.)		
TB COVER	1238.	2028.	0.	623.	0.	2.	2.
					0.	0.	-0.
FRONT SPAR	266.	1934.	0.	623.	0.	0.	0.
					0.	0.	0.
MID SPAR	300.	2035.	0.	623.	0.	0.	0.
					0.	0.	0.
REAR SPAR	229.	2094.	0.	623.	0.	0.	0.
					0.	0.	0.
INTER RIBS	337.	2043.	0.	647.	1.	1.	0.
					0.	0.	0.
CAP RIB	18.	2134.	0.	842.	0.	0.	0.
					0.	0.	0.
HINGE RIB	19.	2130.	0.	805.	0.	0.	0.
					0.	0.	0.
HINGE RIB	35.	2025.	0.	581.	0.	0.	0.
					0.	0.	0.
DRIVE RIB	29.	2076.	0.	709.	0.	0.	0.
					0.	0.	0.
DRIVE RIB	31.	2070.	0.	690.	0.	0.	0.
					0.	0.	0.
ROOT RIB	147.	1985.	0.	507.	0.	0.	0.
					0.	0.	0.
RIBS	1411.	2036.	0.	605.	0.	3.	0.
					0.	0.	1.
TORQUE BOX	2549.	2032.	0.	624.	0.	5.	1.
					0.	0.	1.
COVER	885.	2154.	0.	650.	0.	0.	0.
					0.	0.	0.
FRONT SPAR	37.	2130.	0.	650.	0.	0.	0.
					0.	0.	0.
INTER RIBS	109.	2245.	0.	666.	0.	2.	0.
					0.	0.	0.
CAP RIBS	25.	2159.	0.	608.	0.	0.	0.
					0.	0.	0.
DRIVE RIB	21.	2155.	0.	647.	0.	0.	0.
					0.	0.	0.
HINGE RIB	10.	2200.	0.	766.	0.	0.	0.
					0.	0.	0.
HINGE RIB	6.	2015.	0.	541.	0.	0.	0.
					0.	0.	0.

MASS PROPERTIES SUMMARY 06/09/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
L					(SLUG-FEET SQ./1000.)		
DRIVE RIB	21.	2165.	0.	667.	0.	0.	0.
					0.	0.	0.
RIBS	182.	2205.	0.	659.	0.	2.	2.
					0.	0.	0.
FUSE FTG	96.	2122.	0.	671.	0.	0.	0.
					0.	0.	0.
RUDDER	1260.	2157.	0.	653.	1.	3.	4.
					0.	0.	0.
LEADING EDGE	731.	1970.	0.	623.	0.	1.	1.
					0.	0.	0.
CONT'G	464.	2056.	0.	632.	0.	0.	0.
					0.	0.	0.
V-TAIL	5104.	2056.	0.	632.	2.	13.	13.
					0.	0.	2.

1

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*

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 EDIT TAIL
*TY0-900
   1.000 INCH1014
   2.000 TAIL GROUP
   3.000    1923.    177.
   4.000 SKIN            743.0 2028.    0.   623.   10.   83.   83.   0 19
07. 2179.
   6.000 STRG            495.0 2028.    0.   623.   10.   83.   83.   0 19
07. 2179.
   7.000 TB COVER
         3 0
   8.000 CAPS            203.0 1984.    0.   623.   10.   78.   78.   0 19
07. 2088.
   9.000 WEBS             63.0 1984.    0.   623.   10.   78.   78.   0 19
07. 2088.
  10.000 FRONT SPAR
         4 0
  11.000 CAPS            220.0 2035.    0.   623.   10.   78.   78.   0 19
79. 2134.
  12.000 WEB              80.0 2035.    0.   623.   10.   78.   78.   0 19
79. 2134.
  13.000 MID SPAR
         4 0
  14.000 CAPS            172.0 2094.    0.   623.   10.   78.   78.   0 20
49. 2179.
  15.000 WEB              57.0 2094.    0.   623.   10.   78.   78.   0 20
49. 2179.
  16.000 REAR SPAR
         4 0
  17.000 SPARS
         3 0 or
  18.000 RIB1             17.0 1952.    0.   526.   10.   34.   34.   0 19
07. 2179.
  19.000 RIB2             26.0 1986.    0.   530.   10.   34.   34.   0 19
07. 2179.
  20.000 RIB3             31.0 1997.    0.   545.   10.   33.   33.   0 19
07. 2179.
  21.000 RIB4             30.0 2006.    0.   563.    9.   33.   33.   0 19
07. 2179.
  22.000 RIB5             28.0 2022.    0.   599.    9.   32.   32.   0 19
07. 2179.
  23.000 RIB6             27.0 2030.    0.   617.    9.   32.   32.   0 19
07. 2179.
  24.000 RIB7             25.0 2038.    0.   635.    8.   31.   31.   0 19
07. 2179.
  25.000 RIB8             25.0 2047.    0.   653.    8.   30.   30.   0 19
07. 2179.
  26.000 RIB9             24.0 2055.    0.   671.    8.   30.   30.   0 19
07. 2179.
  27.000 RIB10            21.0 2082.    0.   722.    7.   29.   29.   0 19
07. 2179.
  28.000 RIB11            20.0 2090.    0.   747.    7.   28.   28.   0 19
07. 2179.
  29.000 RIB12            19.0 2099.    0.   767.    7.   27.   27.   0 19
07. 2179.
  30.000 RIB13            18.0 2108.    0.   785.    6.   27.   27.   0 19
07. 2179.
  31.000 RIB14            16.0 2125.    0.   825.    6.   26.   26.   0 19
07. 2179.
  32.000 RIB15             9.0 2155.    0.   835.    6.   26.   26.   0 19
07. 2179.
  33.000 INTER RIBS
         4 0
```

34.000 CAP RIB	18.0	2134.	0.	842.	6.	26.	26.	0	19
07. 2179.									
35.000 CAP RIB									
4 0									
36.000 UPR HINGE	19.0	2130.	0.	805.	7.	29.	29.	0	19
07. 2179.									
37.000 HINGE PIN									
4 0									
38.000 LWR HINGE	35.0	2025.	0.	581.	9.	33.	33.	0	19
07. 2179.									
39.000 HINGE PIN									
4 0									
40.000 UPR DRIVE	28.0	2076.	0.	709.	8.	30.	30.	0	19
07. 2179.									
41.000 DRIVE PIN									
4 0									
42.000 LWR DRIVE	31.0	2070.	0.	690.	8.	30.	30.	0	19
07. 2179.									
43.000 DRIVE PIN									
4 0									
44.000 ROOT RIB	147.0	1985.	0.	508.	10.	33.	33.	0	19
07. 2179.									
45.000 ROOT RIB									
4 0									
46.000 RIBS									
3 0									
47.000 TORQUE BOX									
2 0									
48.000 CLOSE OUT	12.0	2130.	0.	650.	8.	11.	93.	0	20
49. 2264.									
49.000 SKIN	522.0	2170.	0.	650.	8.	11.	93.	0	20
49. 2264.									
49.500 STRUC	351.0	2130.	0.	650.	8.	11.	93.	0	20
49. 2264.									
50.000 COVER									
3 0									
51.000 CAPS	35.0	2130.	0.	650.	8.	11.	93.	0	20
70. 2194.									
52.000 WEB	52.0	2130.	0.	650.	8.	11.	93.	0	20
70. 2194.									
53.000 FRONT SPAR									
3 0									
54.000 RIB4	3.0	2087.	0.	526.	6.	11.	11.	0	20
70. 2264.									
55.000 RIB5	9.0	2115.	0.	553.	6.	11.	11.	0	20
70. 2264.									
56.000 RIB6	11.0	2125.	0.	573.	6.	11.	11.	0	20
70. 2264.									
57.000 RIB7	11.0	2135.	0.	591.	6.	11.	11.	0	20
70. 2264.									
58.000 RIB8	11.0	2145.	0.	606.	6.	11.	11.	0	20
70. 2264.									
59.000 RIB9	10.0	2150.	0.	625.	6.	11.	11.	0	20
70. 2264.									
60.000 RIB10	9.0	3175.	0.	627.	6.	11.	11.	0	20
70. 2264.									
61.000 RIB11	9.0	2180.	0.	707.	6.	11.	11.	0	20
70. 2264.									
62.000 RIB12	7.0	2185.	0.	727.	6.	11.	11.	0	20
70. 2264.									

```
  63.000 RIB13              8.0 2190.    0.   747.    6.   11.   11.   0 20
70. 2264.
  64.000 RIB14              7.0 2205.    0.   787.    6.   11.   11.   0 20
70. 2264.
  65.000 RIB15              7.0 2210.    0.   807.    6.   11.   11.   0 20
70. 2264.
  66.000 RIB16              6.0 2220.    0.   837.    6.   11.   11.   0 20
70. 2264.
  67.000 INTER RIBS
          4 0
  68.000 UPR CAP            6.0 2220.    0.   842.    6.   11.   11.   0 21
34. 2194.
  69.000 LWR CAP           19.0 2130.    0.   534.    8.   11.   11.   0 20
70. 2182.
  70.000 CAP RIBS
          4 0
  71.000 LWR DRIVE         21.0 2155.    0.   647.    6.   11.   11.   0 20
70. 2264.
  72.000 DRIVE RIB
          4 0
  73.000 UPR HINGE         10.0 2200.    0.   766.    6.   11.   11.   0 20
70. 2264.
  74.000 HINGE RIB
          4 0
  75.000 LWR HINGE          6.0 2015.    0.   541.    6.   11.   11.   0 20
7 . 2264.
  76.000 HINGE RIB
          4 0
  77.000 UPR DRIVE         21.0 2165.    0.   667.    6.   11.   11.   0 20
7 . 2264.
  7 .000 DRIVE RIB
          4 0
  7 .000 RIBS
          3 0
  80.000 HINGE             24.0 2164.    0.   723.    2.    2.    2.   0 21
60. 216 .
  81.000 HINGE             24.0 2127.    0.   573.    2.    2.    2.   0 21
3. 2131.
  82.000 HINGE             24.0 2120.    0.   664.    2.    2.    2.   0 21
16. 2124.
  83.000 HINGE             24.0 2075.    0.   553.    2.    2.    2.   0 20
71. 2079.
  84.000 HINGE FTG
          3 0
  85.000 RUDDER
          2 0
  86.000 LEADING EDGE     731.0 1870.    0.   623.   10.   33.   33.   0 18
65. 2080.
  87.000 LEADING EDGE
          2 0
  88.000 CONT'G           464.0 2056.    0.   530.    2.    2.    2.   0 18
65. 2254.
  89.000 CONT'G
          2 0
  90.000 V-TAIL
          1 0
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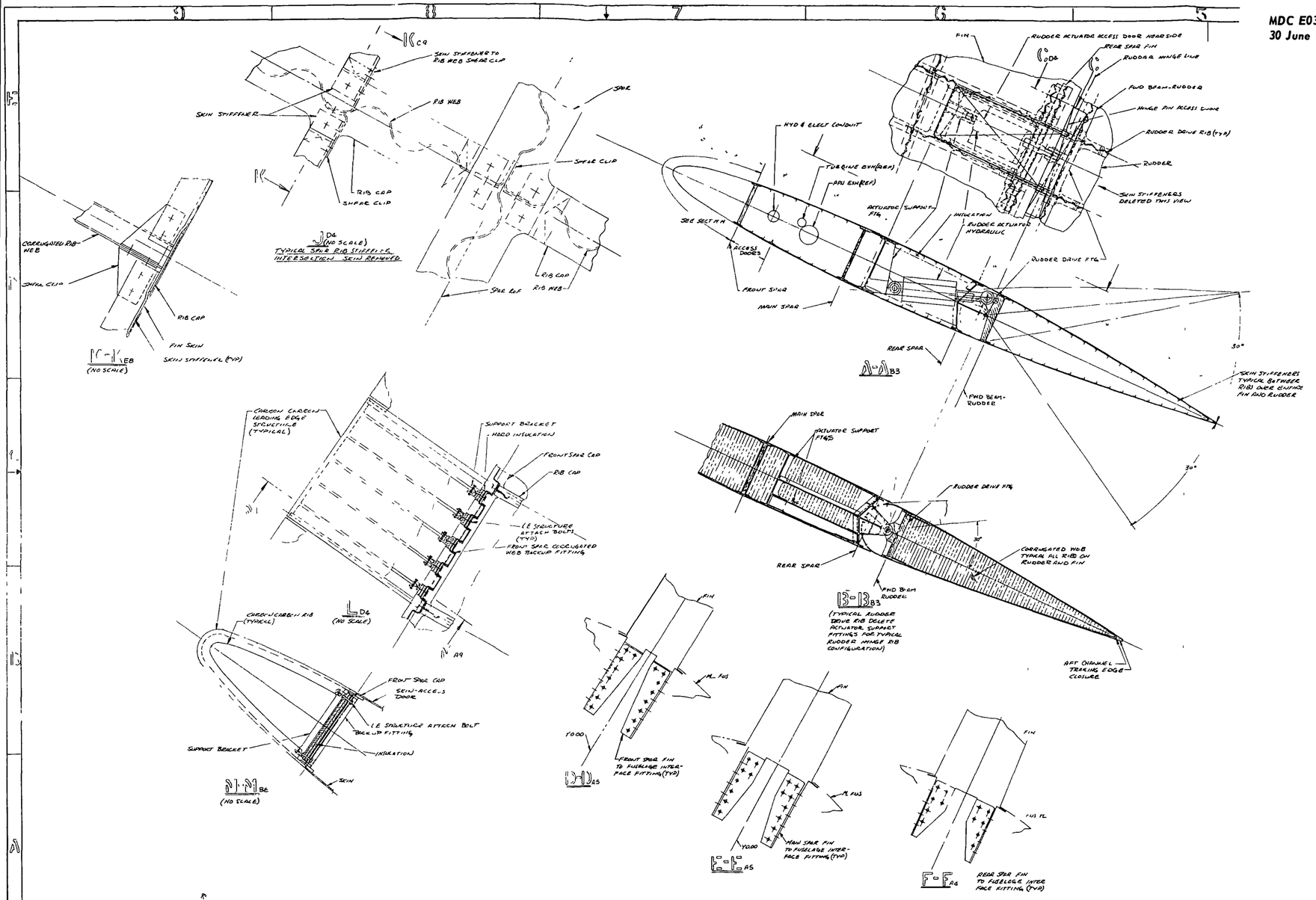

SECURITY CLASSIFICATION	DRAWING NUMBER	SH
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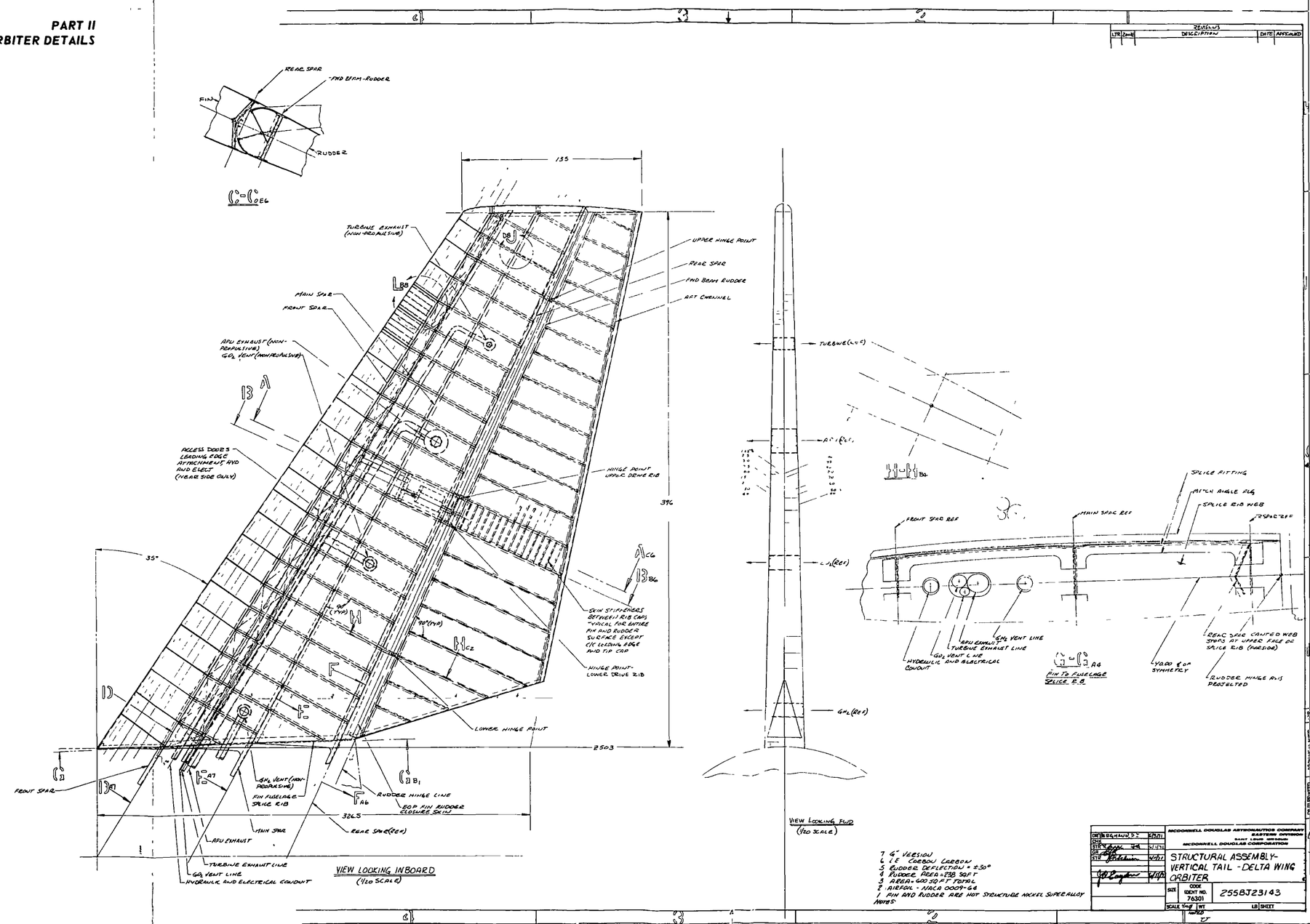
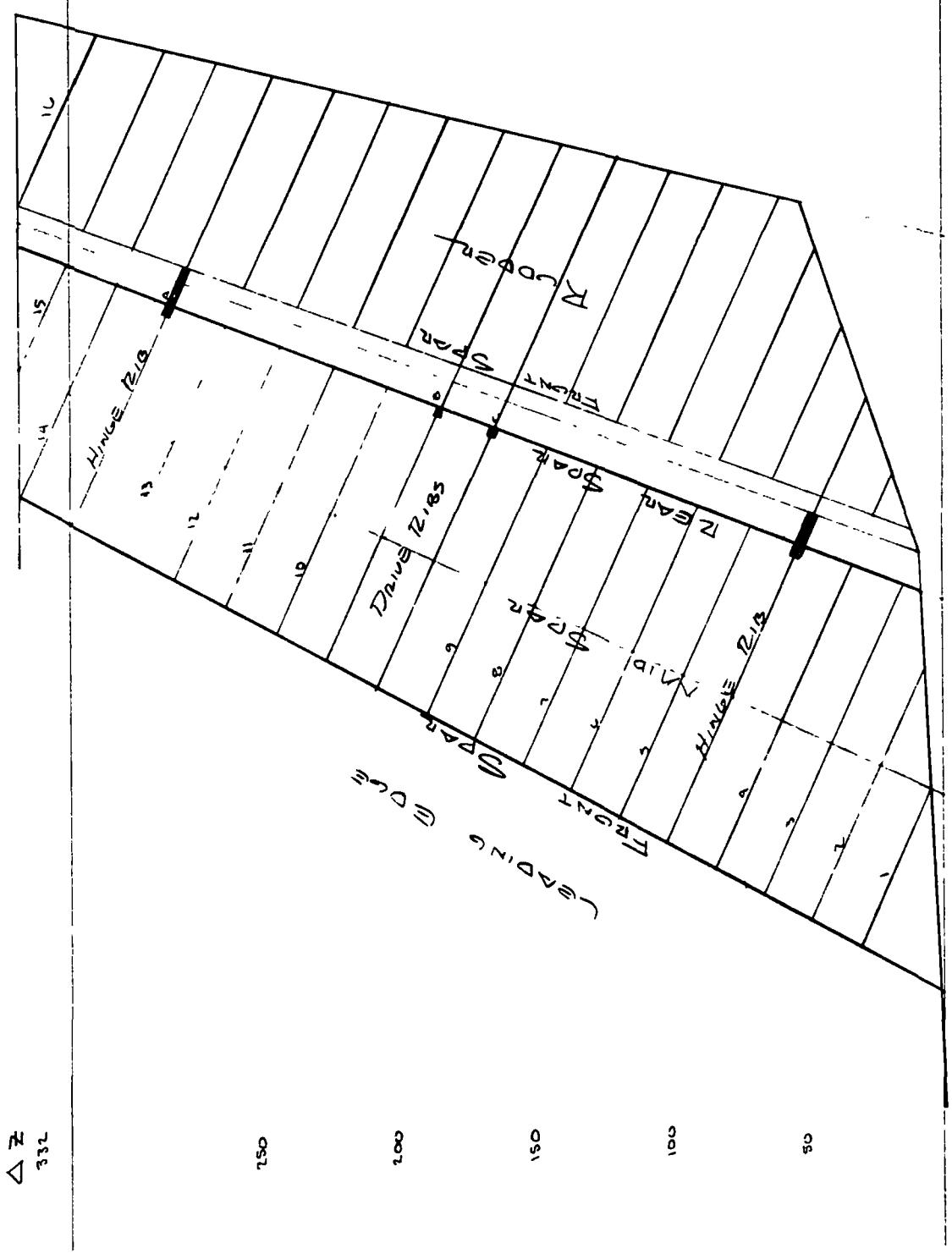

REAR SPAR
END BEAM-RUDDER
FIN
RUDDER
135
TURBINE EXHAUST (NON-PROPULSIVE)
UPPER HINGE POINT
REAR SPAR
END BEAM RUDDER
ART CHANNEL
MAIN SPAR
FRONT SPAR
APU EXHAUST (NON-PROPULSIVE)
GO2 VENT (NON-PROPULSIVE)
RECESS DOORS LEADING EDGE ATTACHMENT, HYD AND ELECT (NEAR SIDE ONLY)
HINGE POINT UPPER DRIVE RIB
396
35°
SKIN STIFFENERS BETWEEN RIB CAPS "VERTICAL FIN ENTIRE FIN AND RUDDER SURFACE EXCEPT C/E LEADING EDGE AND TIP CAP
HINGE POINT-LOWER DRIVE RIB
LOWER HINGE POINT
2503
FRONT SPAR
GH2 VENT (NON-PROPULSIVE)
FIN FUSELAGE SPLICE RIB
RUDDER HINGE LINE
EOP FIN RUDDER CLOSURE SKIN
326.5
REAR SPAR(REF)
MAIN SPAR
APU EXHAUST
TURBINE EXHAUST LINE
GO2 VENT LINE
HYDRAULIC AND ELECTRICAL CONDUIT
VIEW LOOKING INBOARD
(1/20 SCALE)
TURBINE(REF)
SPLICE FITTING
MATCH ANGLE FLG
SPLICE RIB WEB
FRONT SPAR REF
MAIN SPAR REF
GH2 VENT LINE
APU EXHAUST TURBINE EXHAUST LINE
GO2 VENT LINE
HYDRAULIC AND ELECTRICAL CONDUIT
FIN TO FUSELAGE SPLICE R.B.
REAR SPAR CANTED WEB STOPS AT UPPER FACE OF SPLICE RIB (TYP.)
YAW ℄ OF SYMMETRY
RUDDER HINGE AXIS REORIENTED
VIEW LOOKING RWD
(1/20 SCALE)
7 G' VERSION
6 E CARBON/CARBON
5 RUDDER DEFLECTION = ±30°
4 RUDDER AREA=238 SQ FT
3 AREA=603 SQ FT TOTAL
2 AIRFOIL - NACA 0007-64
1 FIN AND RUDDER ARE HOT STRUCTURE NICKEL SUPERALLOY
NOTES:
DES
CHK
STR
GP
PROJ
MCDONNELL DOUGLAS ASTRONAUTICS COMPANY EASTERN DIVISION
SAINT LOUIS, MISSOURI
MCDONNELL DOUGLAS CORPORATION
STRUCTURAL ASSEMBLY-VERTICAL TAIL - DELTA WING ORBITER
SIZE
CODE IDENT NO. 76301
2558J23143
SCALE
WT
LB
SHEET

5-18-71	J GARRISON	VERTICAL TAIL	GEOMETRY	2/



DERIVATION OF NON OPTIMUM

ON THE SKINS A PAD WILL BE REQUIRED FOR ATTACHMENT OF COUNTERSUNK RIVETS. THE PAD WOULD BE 030 THICK, BRINGING TOTAL THICKNESS TO 050 AT THE POINT OF ATTACHMENT. ON A 2.4 INCH STRINGER PITCH THE PENALTY BECOMES

$$(2.4 * 020 + .75 * 030)\frac{1}{2.4} = 028$$

$$\frac{028}{020} - 1 = 40\% \text{ BASIC SKIN INCREASE}$$

IT SHOULD BE NOTED THAT THIS INCREMENT APPLIES ONLY TO THE SKIN.

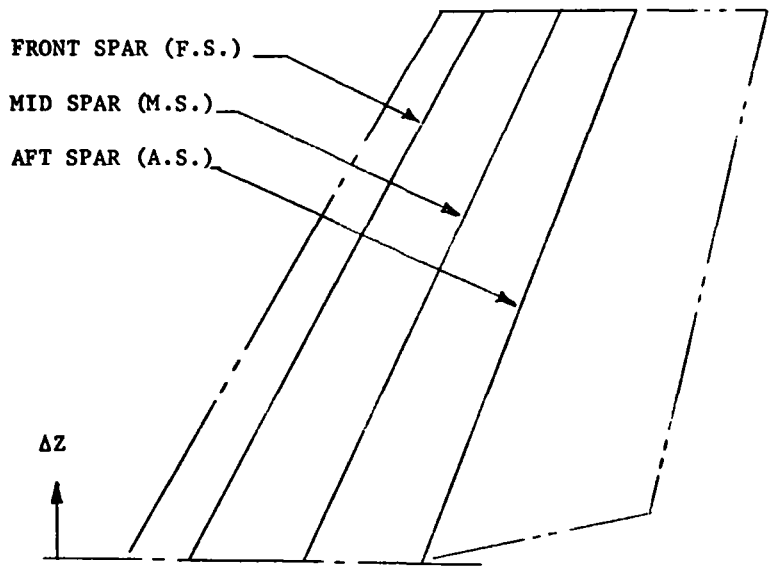
STANDARD NON OPTIMUM OF 10% FOR GAGE AND MILLING IS USED ON ALL ITEMS AS WELL AS 10% FOR SPLICES AND ATTACHMENTS.

TORQUE BOX SUMMARY

ITEM	IDEAL WT	NON OPTIMUM
COVER MAT'L	774	464
FRONT SPAR	222	44
MID SPAR	250	50
AFT SPAR	191	38
INTERMEDIATE RIBS	281	56
DRIVE RIBS	50	10
HINGE RIBS	45	9
CAD RIB	15	3
ROOT ATTACH RIB	123	24
SUB TOTAL	1951	698
TOTAL TORQUE BOX		2649

VERTICAL TAIL

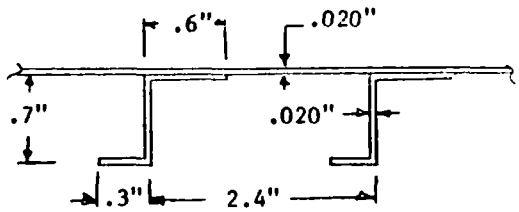
STRENGTH SIZING DATA FOR WEIGHT ANALYSIS



MATERIAL: INCONEL 718

	CAP AREA (BOTH)			SPAR DEPTH			WEB THICKNESS ($\bar{t}$)		
ΔZ	F.S. IN^2	M.S. IN^2	A.S. IN^2	F.S. IN.	M.S. IN.	A.S. IN.	F.S. IN.	M.S. IN.	A.S. IN.
0	3.84	4.18	3.28	23.7	27.4	21.7	.0263	.0332	.0286
50	2.84	3.18	2.48	22.4	25.9	20.5	.0242	.0306	.0266
100	2.04	2.26	1.78	21.1	24.4	19.3	.0242	.0278	.0242
150	1.38	1.49	1.28	19.8	22.9	18.1	.0242	.0252	.0242
200	1.0	1.06	.92	18.5	21.4	17.0	.0242	.0242	.0242
250	.6	.64	.56	17.2	19.9	15.8	.0242	.0242	.0242
332	.22	.22	.22	15.	17.4	13.8	.0242	.0242	.0242

TORQUE BOX COVERS



Vertical Tail

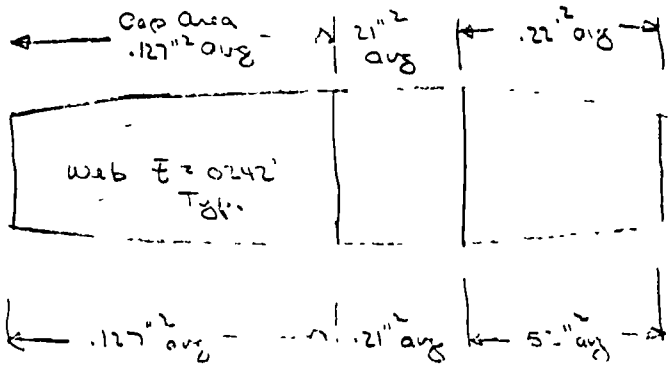
Data For Weights Analysis

Intermediate Ribs @ 20" Spacing

Webs ~ $\bar{t}$ = .0242 (t = .020 corrugated web)

Caps. .069"^{2} each.

Drive Ribs (2 drive ribs)



Upper Hinge Rib, Cap Area = .105"^{2} each

Lower Hinge Rib, Cap Area = .13"^{2} each.

$\bar{t}$ webs = .0242

4/

THE BASIC SHELL IS 020 INCONEL 718 WITH Z STRINGERS ON 2.4 IN CENTERS

$\bar{t} = (2.4 + .64 + .3)\frac{1}{2.4} * .020 = .0333$

TORQUE BOX SURFACE AREA FROM GEOMETRY SKETCH

$(193 + 92)\frac{1}{2} * 333 = 39100 \text{ IN}^2 = 271.5 \text{ FT}^2$

COVER MAT'L WT

$39100 * .0333 * .297 = 387 \text{ LB/SIDE}$ 774 LB

FRONT SPAR

Sta	L	CAP x-Sec	Vol	h	$\bar{t}$	WEB x Sec	Vol
0		3.84		23.7	.0263	.623	
	55		183.8				32.0
50		2.84		22.4	.0242	.542	
	56		136.5				29.5
100		2.04		21.1		.510	
	56		95.8				27.6
150		1.38		19.8		.479	
	56		66.6				25.9
200		1.0		18.5		.448	
	56		44.8				24.2
250		.6		17.2		.417	
	102		41.8				39.8
338		.22		15	.0242	.363	

Σ CAP VOL 569.3 IN³ Σ WEB VOL 179.0 IN³

TOTAL VOL = 748.3 IN³

WT = 748 * .297 = 222 LB

5/

MID SPAR

Δz	L	CAP X-Sec	Vol	h	t̄	Web X-Sec	Vol
0		4.18		27.9	.0332	.91	
	55		203.0				46.8
50		3.18		25.9	.0806	.792	
	55		149.5				40.9
100		2.26		24.4	.0278	.678	
	55		103.0				34.6
150		1.49		22.9	.0254	.582	
	55		70.2				30.3
200		1.06		21.4	.0242	.518	
	55		46.7				27.5
250		.64		19.9	.0242	.482	
	99		42.7				44.7
338		.22		17.4	.0242	.422	

Σ cap Vol = 615.1 in³ Σ web Vol = 224.8 in³

Wt = 839.4 * .297 = 250 LB

AFT SPAR

Δz	L	CAP X-Sec	Vol	h	t̄	Web X-Sec	Vol
0		3.28		21.7	.286	.62	
	53		154.0				30.9
50		2.48		20.5	.266	.546	
	53		113.0				26.9
100		1.78		19.3	.242	.467	
	53		81.1				24.0
150		1.28		18.1		.438	
	53		58.3				22.5
200		.92		17.0		.412	
	53		39.2				21.0
250		.56		15.8		.382	
	96		37.5				34.4
338		.22		13.8	.242	.334	

Σ cap Vol = 483.1 in³ Σ web Vol = 159.7 in³

Wt = 642.8 * .297 = 191 LB

6/

RIBS @ 20 IN SPACING

ALL WEBS ARE CORRUGATED WITH $\theta = 60°$
AND A MINIMUM GAGE OF 020

INTERMEDIATE RIBS
ALL WEBS 020 MIN , 0242 Ē
ALL CAPS 069 IN² EACH

1. L = 63 IN

CAPS	63 * 069 * 2	= 8.7	
WEB	(22.5+27.5)½ * 63 * 0242	= 38.1	
		46.8 * .297	= 13.9 LB

2 L = 100 IN

CAPS	100 * 069 * 2	= 13.8	
WEB	62 (22+27)½ * 0242	= 36.7	
	38 (27+21)½ * 0242	= 22.1	
		72.6 * .297	= 21.6 LB

3. L = 124 IN

CAPS	124 * 069 * 2	= 17.1	
WEB	60 (21.5+26.5)½ * 0242	= 34.9	
	64 (26.5+20)½ * 0242	= 36.0	
		88.0 * .297	= 26.2 LB

4 L = 59 + 63

CAPS	122 * 069 * 2	16.8	
WEB	59 (21+25.5)½ * 0242	33.2	
	63 (25.5+20)½ * 0242	34.7	
		84.7 * .297	= 25.2 LB

5 L = 57 + 60

CAPS	117 * 069 * 2	16.2	
WEB	57 (20 + 24.5)½ * 0242	30.7	
	60 (24.5+19.5)½ * 0242	31.9	
		78.8 * .297	= 23.4 LB

6 L = 56+ 58

CAPS	114 * 069 * 2	15.7	
WEB	56 (20+24)½ * 0242	29.8	
	58 (24+19)½ * 0242	30.2	
		75.7 * .297	= 22.5 LB

7/

7 L = S4 + S8

CAPS	112 * 069 * 2	15.5
WEB	S4 (19.5 + 23.5) ½ * 0242	28.1
	S8 (23.5 + 19) ½ * 0242	29.9
		73.5 * .297 = 21.8 LB

8. L = S3 + S6

CAPS	109 * 069 * 2	15.0
WEB	S3 (19 + 23) ½ * 0242	26.9
	S6 (23 + 18.5) ½ * 0242	28.1
		70.0 * 297 = 20.8 LB

9. L = S2 + S5

CAPS	107 * 069 * 2	14.7
WEB	S2 (19 + 22.5) ½ * 0242	26.1
	S5 (22.5 + 18) ½ * 0242	26.9
		67.7 * 297 = 20.1 LB

10 L = A8 + S1

CAPS	99 * 069 * 2	13.7
WEB	A8 (17.5 + 21) ½ * 0242	22.4
	S1 (21 + 16.5) ½ * 0242	23.1
		59.2 * .297 = 17.6 LB

11 L = A7 + A9

CAPS	96 * 069 * 2	13.2
WEB	A7 (17 + 20) ½ * 0242	21.1
	A9 (20 + 16) ½ * 0242	21.3
		55.6 * .297 = 16.5 LB

12 L = A6 + A8

CAPS	94 * 069 * 2	13.0
WEB	A6 (17 + 19.5) ½ * 0242	20.3
	A8 (19.5 + 15.5) ½ * 0242	20.3
		53.6 * .297 = 16.0 LB

8/

13. L = 44 + 47

Caps	91 * 069 * 2	12.5	
Web	44 (16+14) ½ * 0242	18.7	
	47 (14+15) ½ * 0242	19.3	
		50.5 * .297	= 15.0 lb

14. L = 42 + 44

Caps	86 * 069 * 2	11.9	
Web	42 (15.5+17.5) ½ * 0242	16.8	
	44 (17.5+14) ½ * 0242	16.8	
		45.5 * .297	= 13.5 lb

15. L = 42

Caps	= 42 * 069 * 2	5.8	
Web	= 42 (17.9+19) ½ * 0242	16.0	
		21.8 * .297	= 6.5 lb

TOTAL INTERMEDIATE RIBS 280.6 LB

CAP RIB L = 46 + 45

Caps	91 * 069 * 2	=	12.6
Web	46 (15+17.4) ½ * 0242	=	18.0
	45 (17.4+18.8) ½ * 0242	=	17.9
		48.0 * .297	= 14.6

9/

Upper Hinge Rib

Cap Area 105 in² each
Web t̄ = .0242

L = A3 + A5

Caps	88 * 105 * 2	18.5
Web	A3 (16+18)½ * 0242	17 7
	A5 (18+15)½ * 0242	180
		54 2 * 297 = 16.1 LB

Lower Hinge Rib

Cap Area = 180 in² each
Web t̄ = 0242

L = 58 + 61

119 * .13 * 2	30.9
58 (21+25) ½ * 0242	32 3
61 (25+20) ½ * 0242	33.3
	96 5 * 297 = 28.7 LB

Upper Drive Rib

Cap Area = .127 in² FWD 22 in² AFT
Web t̄ = 0242
L = A9 + 52

Caps	A9 * .127 * 2	12.5
	52 * .220 * 2	22.9
Web	A9 (18+21) ½ * 0242	23.1
	52 (21 + 17) ½ * 0242	23.4
		82 A * .297 = 24.5 LB

Lower Drive Rib

Cap Area = 127 in² FWD .22 in² AFT
Web t̄ = 0242
L = 51 + 53

Caps	51 * .127 * 2	13.0
	53 * .220 * 2	23 3
Web	51 (18 5 + 21.5) ½ * 0242	24 7
	53 (21.5 + 17 5) ½ * 0242	25 0
		86 0 * 297 = 25 6 LB

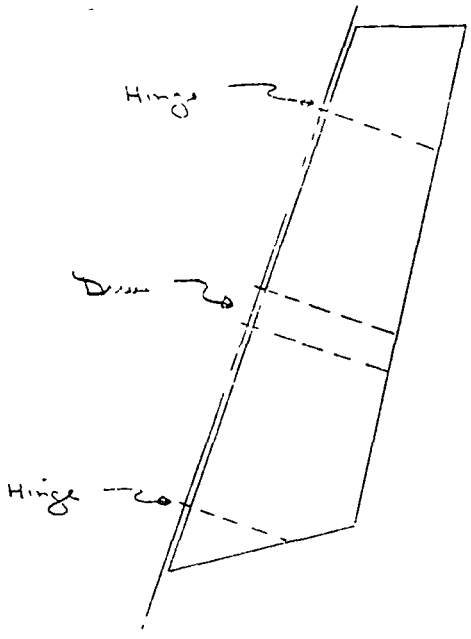
RUDDER SUMMARY

ITEM	IDEAL WT	NON OPTIMUM
COVER MATERIAL	546	327
SPAR	73	14
HINGE RIBS (2)	13	3
DRIVE RIBS (2)	35	7
INTERMEDIATE RIBS (13)	91	18
CAP RIBS (2)	21	4
RUDDER CLOSE OUT SKIN	10	2
HINGE FTG (4)	80	16
SUB TOTAL	869	391
TOTAL RUDDER	1260	

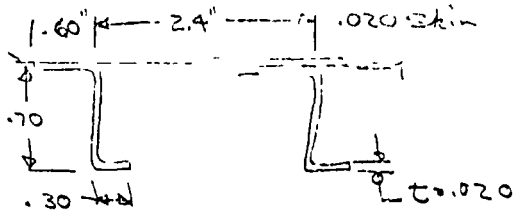
Rudder
Rev F Config

R. Lee
19 ...

Data For Weights Analysis
Material Inconel 718



Torque Box Covers.



Span Cap Area = .14"² each, Avg

Span web t=.020 $\bar{t}$ = .0242

Drive Rib. Area Cap = .354"² each fwd to .09"² each
(2 drive ribs) at Trailing edge.

All ribs have .020 webs, $\bar{t}$ = .0292

Hinge Rib, Upper Area Cap = .083"² each

Hinge Rib, Lower Area Cap = .083" each

Intermediate Rib. Area Cap = .050" each
@ 20" spacing

RUDDER

SURFACE AREA

338 (70+112)½ = 30750
- (53+12)½ * 108 = -3150
27600 IN² = 191.5 FT²

COVER MAT'L - SAME AS TORQUE BOX

27600 * 0333 * .297 = 273 LB/SIDE

546 LB

SPAR

L = 348 IN
W_T = 13.5
W_B = 21.4
CAP x.52L = .19 IN² EACH
WEB t = 020 t̄ = 0242

CAP = 348 * .19 * 2 = 97.5
WEB = 348 (21.4+13.5)½ * 0242 = 147.0
244.5 * 297 = 72.5 LB

UPR HINGE RIB L = 77 IN
CAPS 77 * 083 * 2 = 12.8
WEB 14.5 * ½ * 77 * 0242 = 13.5
26.3 * .297 = 7.8 LB

LWR HINGE RIB L = 40 IN
CAPS 40 * 083 * 2 = 6.6
WEB (14.5+7)½ * 40 * 0242 = 10.4
17.0 * 297 = 5.0 LB

UPR DRIVE RIB L = 88
CAPS 88 * (.354 + 09)½ * 2 = 39.1
WEB 88 (16.5)½ * 0242 = 17.6
56.7 * 297 = 17.1 LB

LWR DRIVE RIB L = 91
CAPS 91 * (354 + .09)½ * 2 = 40.4
WEB 91 * 17 * 12 * 0242 = 18.2
58.6 * 297 = 17.4 LB

INTERMEDIATE RIBS
CAP x-sec = .050 in²
Webs t=.020 $\bar{E}$ = .0242

4 L= 17 in
Caps 17 * .050 * 2 = 1.7
Web 17 (19.5 + 18) ½ * .0242 = 7.7
9.4 * .297 = 2.8 LB

5 L= 61 in
Caps 61 * .050 * 2 = 6.1
Web 61 (19 + 7) ½ * .0242 = 19.2
25.3 * .297 = 7.5 LB

6 L= 85 in
Caps 85 * .050 * 2 = 8.5
Web 85 (18.5 + 3) ½ * .0242 = 22.1
30.6 * .297 = 9.1 LB

7. L= 98 in
Caps 98 * .050 * 2 = 9.8
Web 98 * 18.5 * ½ * .0242 = 21.9
31.7 * .297 = 9.4 LB

8 L= 95 in
Caps 95 * .050 * 2 = 9.5
Web 95 * 18 * ½ * .0242 = 20.7
30.2 * .297 = 9.0 LB

9 L= 93 in
Caps 93 * .050 * 2 = 9.3
Web 93 * 17.5 * ½ * .0242 = 19.6
28.9 * .297 = 8.6 LB

10. L= 86 in
Caps 86 * .050 * 2 = 8.6
Web 86 * 16 * ½ * .0242 = 16.6
25.2 * .297 = 7.5 LB

11. L= 84 in
Caps 84 * .050 * 2 = 8.4
Web 84 * 15.5 * ½ * .0242 = 15.8
24.2 * .297 = 7.2 LB

12 L= 81
CAPS 81 * .050 * 2 = 8.1
WEB 81 * 15 * ½ * .0242 = 14.7
22.8 * .297 = 6.8 LBS

13 L= 79
CAPS 79 * .050 * 2 = 7.9
WEB 79 * 14.5 * ½ * .0242 = 13.9
21.8 * .297 = 6.5 LB

14 L= 74
CAPS 74 * .050 * 2 = 7.4
WEB 74 * 13.5 * ½ * .0242 = 12.1
19.5 * .297 = 5.8 LB

15 L= 72
CAPS 72 * .050 * 2 = 7.2
WEB 72 * 13.5 * ½ * .0242 = 11.7
18.9 * .297 = 5.6 LB

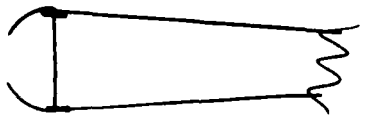
16 L= 69
CAPS 69 * .050 * 2 = 6.9
WEB 69 * 13 * ½ * .0242 = 10.8
17.7 * .297 = 5.3 LB

TOTAL INTERMEDIATE RIBS = 91.1 LB

UPR CAP RIB
L= 70
CAPS 70 * .050 * 2 = 7.0
WEB 70 * 13 * ½ * .0242 = 11.0
18 * .297 = 5.4 LB

LWR CAP RIB
L= 126
CAPS 126 * .090 * 2 = 22.7
WEB 126 * 19 * ½ * .0242 = 29.0
51.7 * .297 = 15.4 LB

RUDDER CLOSE-OUT SKIN



15 *2 * 348 *0333 *.297 = 10.3 LB

DETAIL WEIGHT STATEMENT
BODY GROUP

Item	Weight	Summary Index	Calculations Page No.
Body Group	55500		
Integral Tankage	[20648]		
Fuel Tank	(9734)	2.3-8	
Sidewall	8864		2.3-21-25
Baffles	282		2.3-38
Aft Bkhd	588		2.3-35
Oxidizer Tank	(6042)	2.3-8	
Sidewall	5670		2.3-26-32
Baffles	224		2.3-38
Fwd Bkhd	144		2.3-36
Common Bulkhead	(2876)	2.3-8	2.3-37
Insulation	(1996	2.3-8	2.3-39
Basic Structure	[21824]		
Fwd Section	(5292)	2.3-9	
Sidewall	1928		2.3-45-50
Bulkhead	2664		2.3-51-59
Longerons	700		2.3-40-44
Center Section	(9548)	2.3-9	
Sidewall	2566		2.3-45-50
Bulkheads	5928		2.3-51-74
Longerons	1054		2.3-40-44
Skirt Section	(6984)	2.3-10	
Sidewall	2105		2.3-96 &102-104
Frames	3609		2.3-75-85&97-101
Thrust Post	1270		2.3-105-114
Secondary Structure	[7982]		
Doors	(3318)	2.3-10	2.3-122-131
Payload Door	1819		
Payload Door Mech.	1051		
LH_2 OMS Tank Access	448		
Crew Compartment	(1799)	2.3-10	2.3-115-120
Crew Cab	548		
Airlock	625		
Windshield	385		
Hatches	241		
Equipment Compartment	(631)	2.3-10	2.3-121
Fwd Cpt	507		
Aft Cpt	124		
Speed Brake	(534)	2.3-11	2.3-132
Structural Prov.	(330)	2.3-11	
Nose Gear Prov.	330		2.3-136
Interstage	(1370)	2.3-11	2.3-133-135
Contingency	[5046]		2.3-4

DETAIL WEIGHT SUBSTANTIATION
BODY GROUP

3. BODY GROUP					55500
INTEGRAL TANKAGE				20648	
FUEL TANK			9734		
OXIDIZER TANK			6042		
BETWEEN TANKS (CMN BLKHD)			2876		
INSULATION			1996		
BASIC STRUCTURE	FWD. (5292)	CTR. (9548)	SKIRT (6984)	21824	
SIDEWALLS	1928	2566	2105		
BULKHEADS	2664	5928	3609		
LONGERONS	700	1054	INC'L		
THRUST STRUCTURE (MAIN ASCENT ENGINE)			1270		
SECONDARY STRUCTURE				7982	
CREW COMPARTMENT			1799		
EQUIPMENT COMPARTMENTS			631		
SPEED BRAKES			534		
ENGINE HEAT PROTECTION			*		
INTERSTAGE			1370		
DOORS/FAIRINGS			3318		
MISC GEAR PROVISIONS			330		
CONTINGENCY				5046	

* INC'L IN TPS

THE BODY GROUP, AS GEOMETRICALLY DEFINED BY DWG 2558J000500, IS BROKEN DOWN INTO THREE MAJOR SUBSYSTEMS.

INTEGRAL TANKAGE CONSISTS OF THE MAIN ASCENT TANKS, TANK BULKHEADS, INTERNAL BAFFLES AND INTERNAL INSULATION. THE PRIMARY CONSTRUCTION CONSISTS OF WELDMENTS FROM 2219 ALUMINUM MILLED COMPONENTS.

BASIC STRUCTURE CONSISTS OF:

SIDEWALL – CONTAINING SIDE TITANIUM SHEAR PANELS AND BOLTED ALUMINUM STRINGERS, FWD AND AFT TANK EXTENTION, STRUCTURAL COVERING AROUND THE SIDE SHEAR PANELS, SKIRT SHEAR DECK & CONICAL SECTION AND SKIRT SIDEWALL AND STRINGERS.

BULKHEADS - CONTAINS TANK RINGS, UPPER SIDE FRAMES AND MAJOR BULKHEADS.

LONGERON - CONTAINS THE WL 425 LONGERON WHICH SERVES AS THE CARGO DOOR BOUNDARY

THRUST POSTS - CONTAINS THE THRUST POSTS, STRUTS AND FITTINGS.

THE BASIC STRUCTURE IS BROKEN DOWN INTO THREE BASIC SECTIONS-

THE FORWARD SECTION RUNS FROM THE NOSE TO FS 1076 (NOT INCLUDING 1076 BLKHD)

THE CENTER SECTION RUNS FROM THE FORWARD TO THE AFT END OF THE PAYLOAD BAY FS 1076 TO 1865. (INCLUDES THE 1076 BLKHD BUT NOT THE 1865 BLKHD)

THE SKIRT SECTION RUNS FROM FS 1865 AFT (INCLUDING THE 1865 BLKHD)

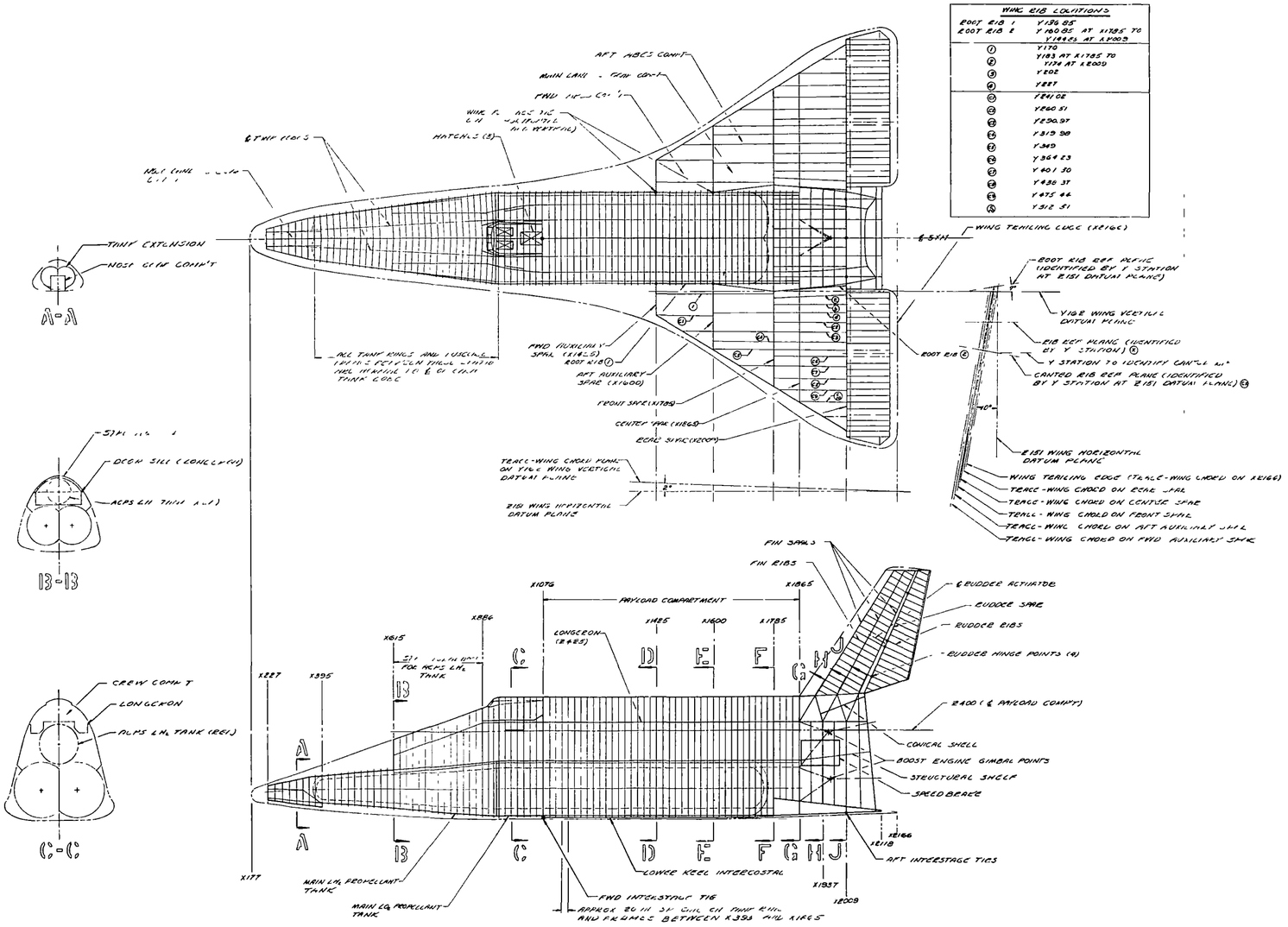
THE SECONDARY STRUCTURE WITH THE EXCEPTION OF THE INTERSTAGE (BOOSTER CONNECT DRAG LONGERON) CONTAINS THE NON PRIMARY LOAD CARRYING STRUCTURE

THE STRENGTH REQUIRED GAGES AND CROSS SECTIONAL AREAS ARE DEFINED IN REPORT NO E0308, SECTION 2.3.1.3 FOR THE EXTERNAL LOADS DEFINED IN REPORT NO E0308, SECTION 2.2.6.2. COPIES OF THE STRUCTURAL SIZING ARE CARRIED WITH THE APPLICABLE STRUCTURAL SUBSYSTEM IN THE WEIGHT ANALYSIS.

THE BODY GROUP WEIGHTS AND INERTIAS ARE SUMMARIZED ON PAGES 2.3-6 AND -7 WITH THE FOLLOWING 3 PAGES BEING THE DETAIL MASS PROPERTIES COMPUTER IN PUT FOR WEIGHT, CG, AND MOMENT OF INERTIA.

NON OPTIMUM FACTORS ARE DERIVED BY TWO METHODS.
ON ITEMS SUCH AS THE INTEGRAL TANKS, WHICH ARE WELL DEFINED STRUCTURALLY AND GEOMETRICALLY, THE NON OPTIMUM IS CALCULATED, CONSIDERING WELD LANDS, MACHINING TOLERANCE, FILLET RADIUS ETC.
ON COMPLEX ITEMS SUCH AS BULKHEADS A 20% INCREASE IS APPLIED TO THE IDEALIZED GAGES TO ALLOW FOR ROUTING DEVELOPMENT AND MANUFACTURING PROBLEMS. TEN PERCENT OF THIS TOTAL IS ASSUMED FOR INSTALLATION.

AS NOTED IN THE INTRODUCTION, SECTION 1.0, THE WEIGHT CONTINGENCY HAS A VARIATION FROM 28% ON CONCEPTUAL WORK TO 15% FOR LAYOUT WORK TO 5% ON CALCULATIONS OF DETAIL DRAWINGS. THE STRUCTURAL WEIGHT ANALYSIS PRESENTED ON THE FOLLOWING PAGES IS FURTHER ADVANCED THAN THE LAYOUT PHASE BUT DOES NOT HAVE THE DEPTH REQUIRED FOR DETAIL DRAWING CALCULATIONS. CONSEQUENTLY A CONTINGENCY OF 10% IS APPLIED TO ALL STRUCTURAL SUBSYSTEMS.


WING RIB LOCATIONS
ROOT RIB 1
ROOT RIB 2
Y 136.85
Y 140.85 AT X1785 TO Y 184.65 AT X2003
1
Y 170
Y 183 AT X1785 TO Y 178 AT X2003
2
Y 202
3
Y 227
4
Y 241.02
5
Y 260.51
6
Y 290.97
7
Y 313.90
8
Y 349
9
Y 364.23
10
Y 401.30
11
Y 438.37
12
Y 475.44
13
Y 512.51
AFT MPEC'S CONFIG
MAIN LAND - TRIM CONFIG
FWD MPEC CONFIG
WING TR. & H ACC TUBE (ELECTRICAL & HYDRAULIC)
HATCHES (3)
B.T.W.P. FLAPS
NOSE CONE CONFIG
TRIM EXTENSION
NOSE GEAR CONFIG
A-A
ACC TRIM RINGS AND FUSELAGE (INCL. INTERFACE TO B.T.W.P. & CENTER TANK) CBDC
FWD AUXILIARY SPAR (X1402.5) ROOT RIB 1
AFT AUXILIARY SPAR (X1600)
FRONT SPAR (X1785)
CENTER SPAR (X1865)
REAR SPAR (X2003)
TRAIL-WING CHORD PLANE ON YIGE WING VERTICAL DATUM PLANE
Z151 WING HORIZONTAL DATUM PLANE
6.5 KH
WING TRAILING EDGE (REIGE)
ROOT RIB REF. PLANE (IDENTIFIED BY Y STATION AT Z151 DATUM PLANE)
YIGE WING VERTICAL DATUM PLANE
RIB REF. PLANE (IDENTIFIED BY Y STATION) 6
ROOT RIB 6
Y STATION TO IDENTIFY CANTED RIB
CANTED RIB REF. PLANE (IDENTIFIED BY Y STATION AT Z151 DATUM PLANE) 13
10°
Z151 WING HORIZONTAL DATUM PLANE
WING TRAILING EDGE (TRAIL-WING CHORD ON X1865)
TRAIL-WING CHORD ON REAR SPAR
TRAIL-WING CHORD ON CENTER SPAR
TRAIL-WING CHORD ON FRONT SPAR
TRAIL-WING CHORD ON AFT AUXILIARY SPAR
TRAIL-WING CHORD ON FWD AUXILIARY SPAR
B-B
C-C
CREW COMPT
LONGERON
ALPS LH2 TANK (REF.)
FIN SPARS
FIN RIBS
X1107.6
X1865
PAYLOAD COMPARTMENT
X886
X615
LONGERON (2 REQ'D)
X1485
X1600
X1785
X227
X395
RUDDER ACTUATOR
RUDDER SPAR
RUDDER RIBS
RUDDER HINGE POINTS (4)
Z400 (@ PAYLOAD COMPT)
CONICAL SHELL
BOOST ENGINE GIMBAL POINTS
STRUCTURAL SHELF
SPEED BRAKE
X2166
X2118
AFT INTERSTAGE TIES
X1937
X2009
LOWER KEEL INTERCOSTAL
FWD INTERSTAGE TIE
APPROX 20 IN SKIN THICKNESS AND FRAMES BETWEEN X395 AND X1865
MAIN LH2 PROPELLANT TANK
MAIN LO2 PROPELLANT TANK
X177

255BJ00142

MASS PROPERTIES SUMMARY 06/10/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY (INCH) X	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
					(SLUG-FEET SQ./1000.)		
LOX TANK	6042.	733.	0.	228.	0.	39.	42.
					0.	0.	-0.
LH2 TANK	9734.	1371.	0.	226.	90.	113.	120.
					0.	0.	0.
COMMON BKHD	2876.	929.	0.	226.	4.	1.	3.
					0.	0.	-0.
LH2 INSUL	1996.	1349.	0.	226.	4.	21.	22.
					0.	0.	0.
INTEG TANK	20648.	1120.	0.	227.	37.	547.	559.
					0.	0.	-1.
RINGS&FRAMES	2664.	841.	0.	304.	6.	18.	18.
					0.	0.	1.
LONGERONS	700.	851.	0.	306.	1.	2.	3.
					0.	0.	-0.
SIDEWALL	1929.	656.	0.	324.	5.	43.	41.
					0.	0.	11.
FWD SECTION	5292.	775.	0.	323.	14.	73.	72.
					0.	0.	12.
LONGERONS	1054.	1505.	0.	425.	2.	12.	14.
					0.	0.	0.
SIDEWALL	2566.	1632.	0.	270.	0.	29.	33.
					0.	0.	-4.
FRAMES	5928.	1453.	0.	273.	21.	84.	92.
					0.	0.	1.
CENTER SEC	9548.	1509.	0.	282.	38.	142.	151.
					0.	0.	-2.
SIDEWALL	2105.	1981.	0.	369.	4.	4.	4.
					0.	0.	0.
FRAMES	3609.	1949.	0.	357.	7.	12.	12.
					0.	0.	-0.
THRUST POST	1270.	1900.	0.	300.	2.	2.	2.
					0.	0.	0.
SKIRT SEC	6984.	1950.	0.	350.	14.	20.	19.
					0.	0.	1.
BASIC STR	21824.	1472.	0.	318.	59.	1141.	1143.
					0.	0.	22.

TS455-000

MASS PROPERTIES SUMMARY 06/10/71

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y	Z	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-RO
					(SLUG-FEET SQ./1000.)		
BODY	3319.	1374.	0.	456.	3.	79.	77.
					0.	0.	0.
CREW CPT	1799.	975.	0.	465.	1.	1.	1.
					0.	0.	-0.
EQUIP CPT	631.	773.	0.	432.	1.	41.	40.
					0.	0.	-6.
P L DEPLOY	0.	0.	0.	0.	0.	0.	0.
					0.	0.	-6.
SPEED BRK	534.	1950.	0.	340.	0.	0.	0.
					0.	0.	0.
STR PROV	330.	315.	0.	200.	0.	0.	0.
					0.	0.	0.
INTERSTAGE	1370.	1423.	0.	150.	0.	12.	12.
					0.	0.	0.
SECONDRY STR	7982.	1240.	0.	395.	30.	356.	326.
					0.	0.	-9.
CONT'G	5046.	1293.	0.	299.	17.	235.	231.
					0.	0.	0.
BODY	55500.	1292.	0.	291.	191.	2605.	2551.
					0.	0.	-2.

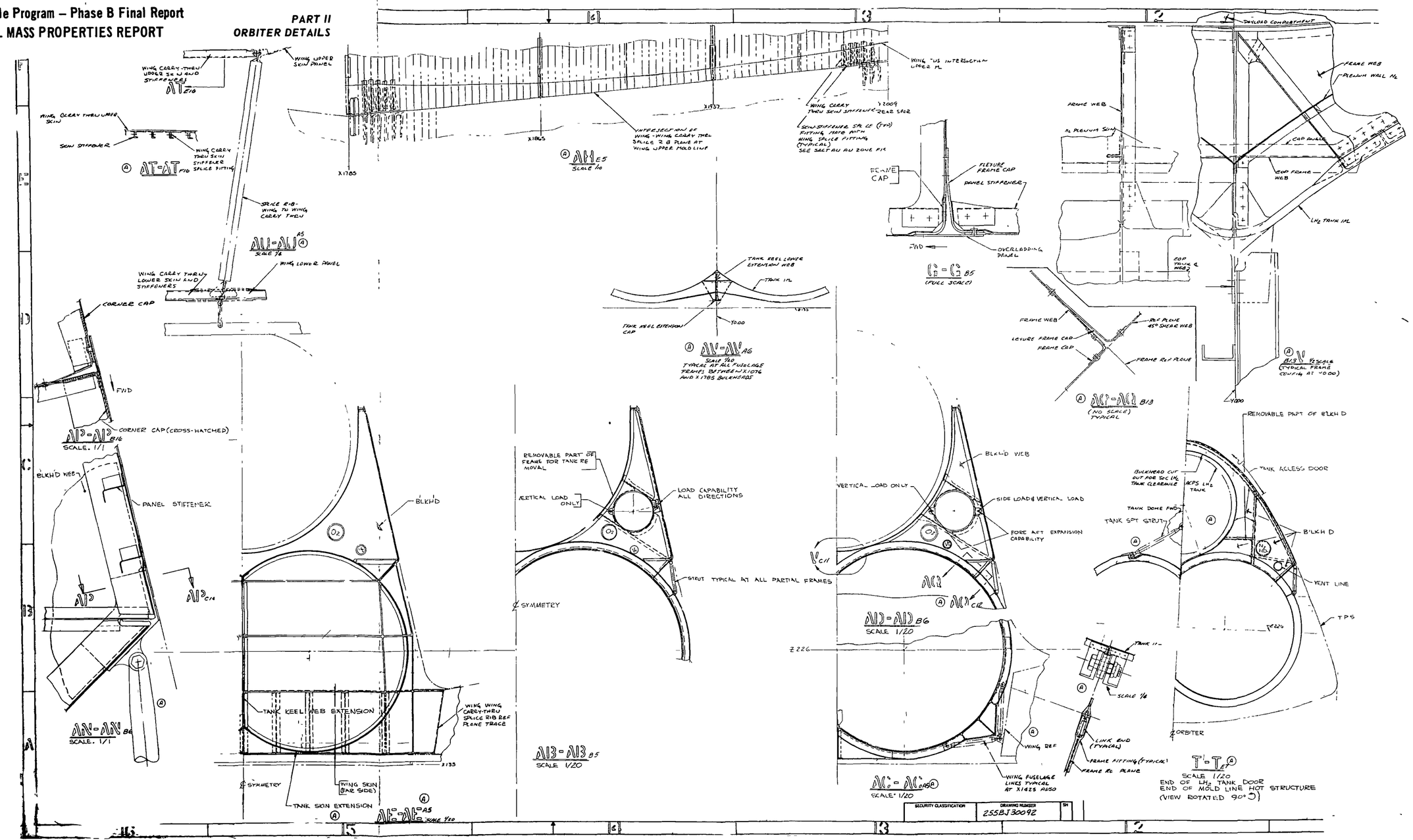
Detail Index

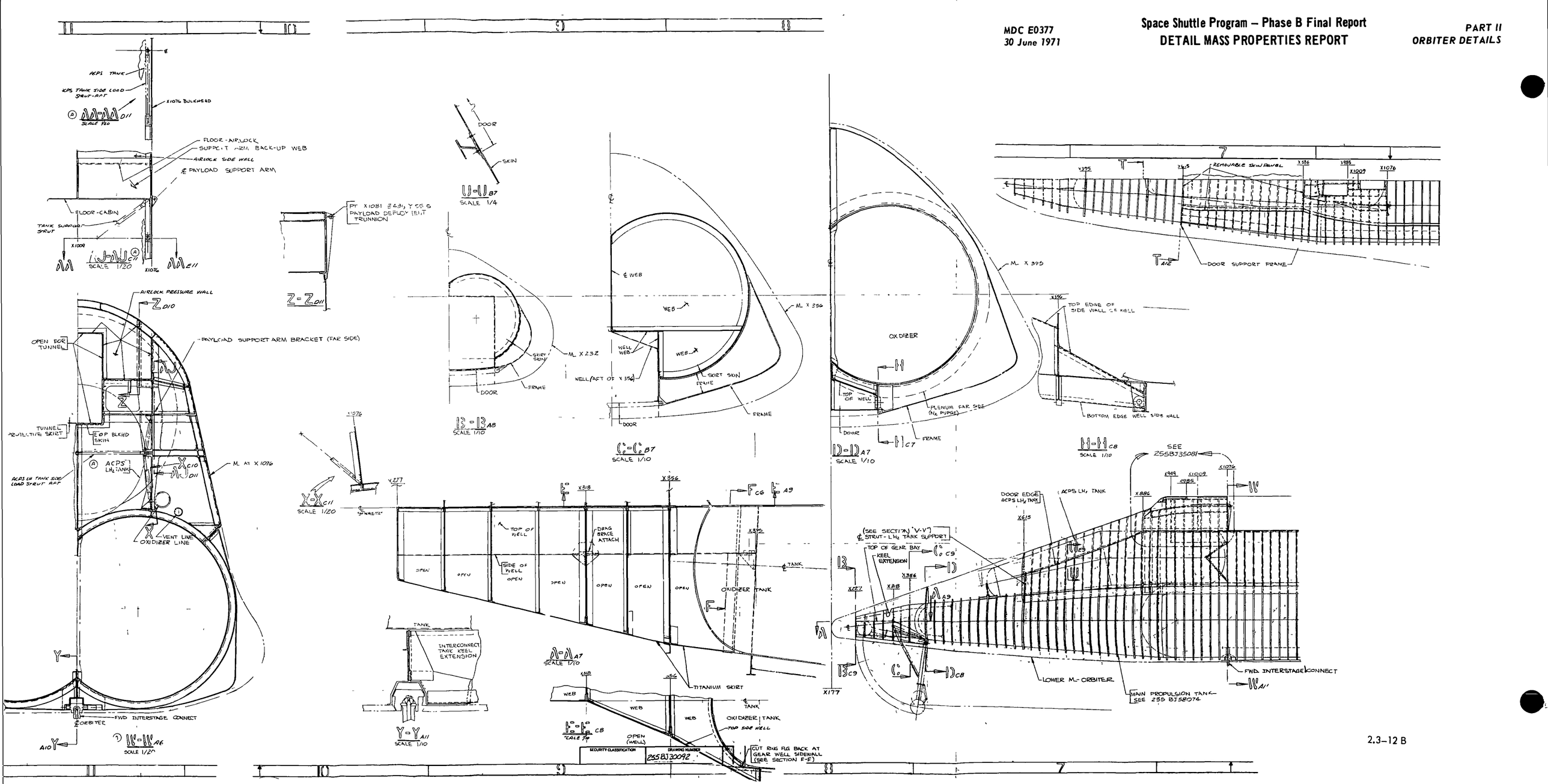
Item						Ref Page
4.000	FWD LOX BKHD	74.	285.	25.	228.	2.3-36
5.000	FWD LOX BKHD	74.	285.	-25.	228.	
6.000	R LOX TANK	2835.	744.	45.	228.	2.3-32
7.000	L LOX TANK	2835.	744.	-45.	228.	
8.000	R LOX BFL	112.	744.	45.	228.	2.3-38
9.000	L LOX BFL	112.	744.	-45.	228.	
10.000	LOX TANK	6042				
11.000	AFT LH2 BKHD	294.	1730.	55.	226.	2.3-35
12.000	AFT LH2 BKHD	294.	1730.	-55.	226.	
13.000	R LH2 TANK	4432.	1348.	55.	226.	2.3-25
14.000	L LH2 TANK	4432.	1348.	-55.	226.	
15.000	R LH2 BFL	141.	1348.	55.	226.	2.3-38
16.000	L LH2 BFL	141.	1348.	-55.	226.	
17.000	LH2 TANK	9734				
18.000	CMN BKHD R	1438.	929.	55.	226.	2.3-37
19.000	CMN BKHD L	1438.	929.	-55.	226.	
20.000	COMMON BKHD	1876				
21.000	R LH2 INS	998.	1348.	55.	226.	2.3-29
22.000	L LH2 INS	998.	1348.	-55.	226.	
23.000	LH2 INSUL	1996				
24.000	INTEG TANK	20648				
25.000	TANK RINGS R	503.	787.	45.	228.	2.3-55
26.000	TANK RINGS L	503.	787.	-45.	228.	
27.000	FRAMES R	829.	873.	80.	350.	2.3-55
28.000	FRAMES L	829.	873.	-80.	350.	
29.000	RINGS&FRAMES	7664				
30.000	LONGERON R	350.	851.	83.	396.	2.3-43
31.000	LONGERON L	350.	851.	-83.	396.	
31.500	LONGERONS	700				

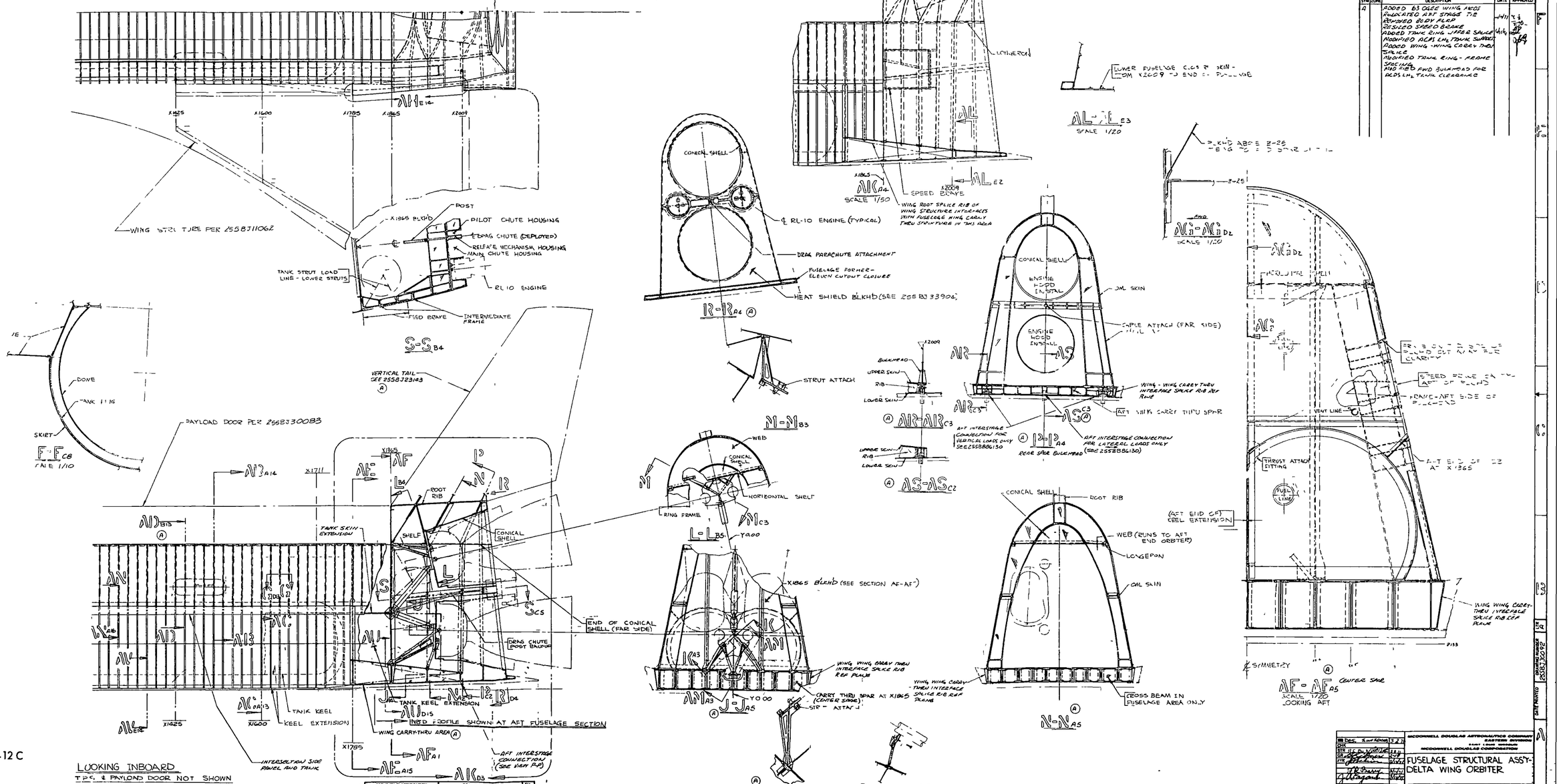
32.000	TANK EXT R	391.	307.	35.	225.	
33.000	TANK EXT L	391.	307.	-35.	225.	
34.000	UPR SKIN	400.	986.	0.	470.	2.3-131
35.000	SHEAR PNL R	373.	846.	80.	350.	2.3-48
36.000	SHEAR PNL L	373.	846.	-80.	350.	
37.000	SIDEWALL	1928				
38.000	FWD SECTION	5292				
39.000	LONGERON R	527.	1525.	100.	425.	2.3-43
40.000	LONGERON L	527.	1525.	-100.	425.	
41.000	LONGERONS	1254				
42.000	SHEAR PNL R	688.	1500.	125.	325.	2.3-50
43.000	SHEAR PNL L	688.	1500.	-125.	325.	
44.000	TANK EXT R	595.	1785.	55.	226.	2.3-96
45.000	TANK EXT L	595.	1785.	-55.	226.	
46.000	SIDEWALL	2566				
47.000	FRAMES R	1422.	1461.	125.	325.	2.3-54
48.000	FRAMES L	1422.	1461.	-125.	325.	
49.000	RINGS R	535.	1446.	55.	226.	2.3-74
50.000	RINGS L	535.	1446.	-55.	226.	
51.000	1076 BKHD	636.	1076.	0.	226.	2.3-63
52.000	1785 BKHD	557.	1785.	0.	226.	2.3-[illegible]
52.500	1425 BKHD	472.	1425.	0.	226.	2.3-67
52.600	1600 BKHD	349.	1600.	0.	226.	2.3-71
53.000	FRAMES	[illegible]				
54.000	CENTER SEC	3518				
55.000	SIDEWALL	1641.	1970.	0.	350.	2.3-[illegible]
55.500	SHELL	175.	2050.	0.	450.	[illegible]
55.600	DECK	289.	2005.	0.	425.	[illegible]
56.000	SIDEWALL	1165				

57.000	1865 BKHD	1175.	1865.	0.	350.	
57.100	1901 FRAME	96.	1901.	0.	350.	
0.	1902.					
57.500	1937 BKHD	465.	1937.	0.	350.	
58.000	2009 BKHD	721.	2009.	0.	350.	
58.200	2049 BKHD	349.	2049.	0.	350.	
58.500	1865 CANTED	205.	1880.	0.	425.	
58.600	1937 CANTED	152.	1920.	0.	425.	
58.700	1971 FRAME	96.	1971.	0.	350.	
59.000	2100 BKHD	349.	2080.	0.	350.	
60.000	FRAMES	3609				
61.000	THRUST POST	1270.	1900.	0.	300.	
62.000	THRUST POST					
63.000	SKIRT SEC	6984				
64.000	BASIC STR					
65.000	PAYLOAD DOOR	1819.	1471.	0.	470.	
65.500	DOOR MECH	1051.	1471.	0.	470.	
66.000	ACCESS DOOR	448.	750.	0.	370.	
67.000	DOORS	3213				
68.000	WINDSHIELD	385.	920.	0.	480.	
69.000	CREW CAB	548.	990.	0.	430.	
70.000	AIRLOCK	625.	990.	0.	480.	
70.500	HATCHES	241.	990.	0.	490.	
71.000	CREW CPT					
72.000	FWD CPT	507.	504.	0.	470.	
73.000	AFT CPT	124.	1875.	0.	275.	
74.000	EQUIP CPT	631				
76.000	P L DEPLOY					

77.000	SPEED BRK	534.	1950.	0.	340.
78.000	SPEED BRK				
81.000	N C ATTCH	330.	315.	0.	200.
82.000	STR PROV				
83.000	INTERSTAGE	1370.	1423.	0.	150.
84.000	INTERSTAGE				
85.000	SECONDRY STR				
86.000	CONT'G	5046.	1293.	0.	289.
87.000	CONT'G				
88.000	BODY				

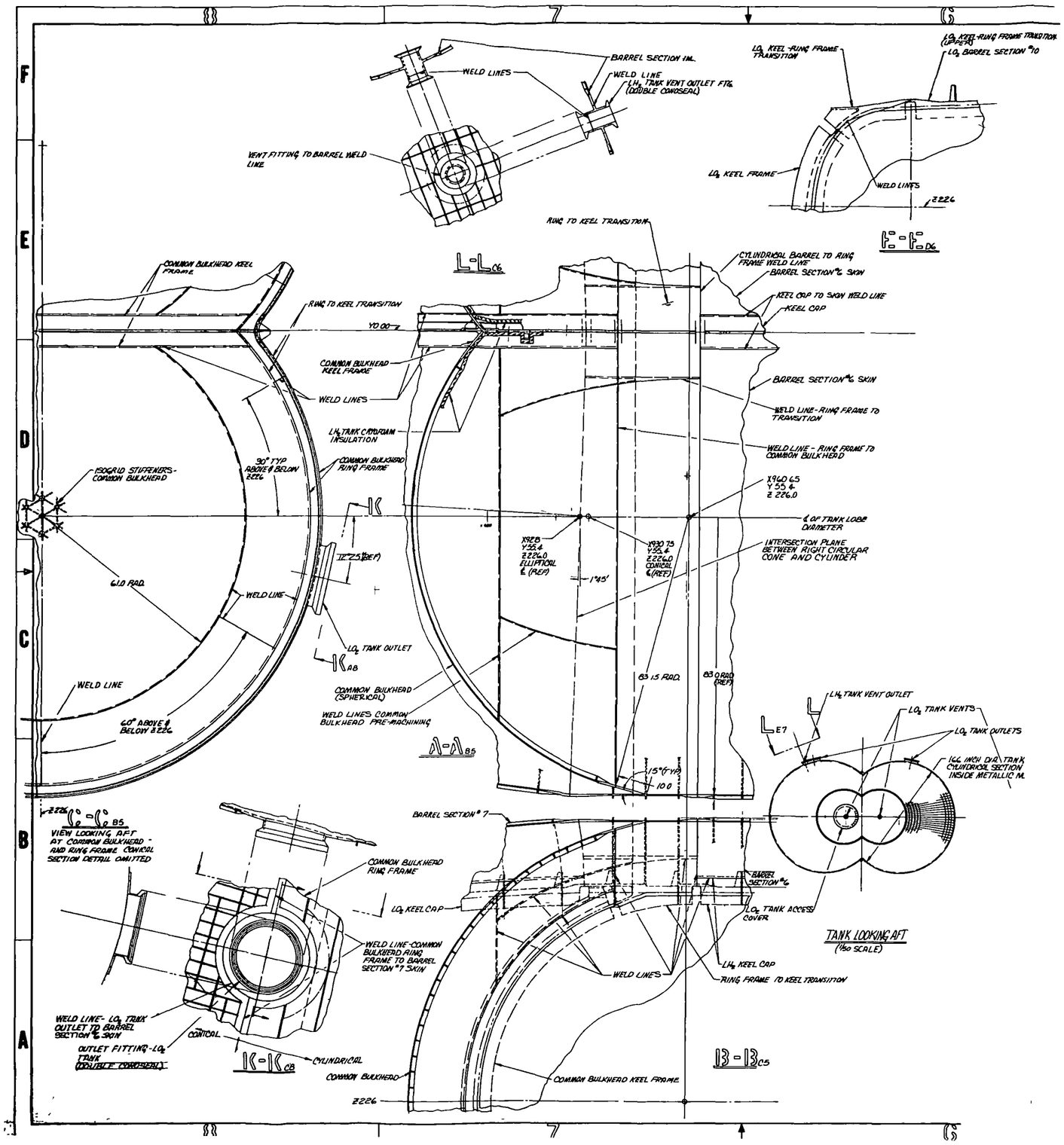

WING CARRY-THRU UPPER SKIN AND STIFFENERS
WING UPPER SKIN PANEL
WING CARRY THRU UPPER SKIN
SKIN STIFFENER
WING CARRY THRU SKIN STIFFENER SPLICE FITTING
SPLICE RIB-WING TO WING CARRY THRU
WING LOWER PANEL
WING CARRY THRU LOWER SKIN AND STIFFENERS
CORNER CAP
FWD
CORNER CAP (CROSS-HATCHED)
SCALE 1/1
BLKHD WEB
PANEL STIFFENER
BLKHD
TANK KEEL WEB EXTENSION
WING WING CARRY-THRU SPLICE RIB REF PLANE TRACE
SYMMETRY
WING SKIN (FAR SIDE)
TANK SKIN EXTENSION
SCALE 1/20
X1785
X1805
WING "US INTERCOSTAL UPPER ML
WING CARRY THRU SKIN STIFFENER
SKIN STIFFENER SPLICE FITTING MATE WITH WING SPLICE FITTING (TYPICAL) SEE SECT AU AV ZONE FIX
INTERSECTION OF WING-WING CARRY THRU SPLICE 2.8 PLANE AT WING UPPER MOLD LINE
SCALE 1/6
TANK KEEL LOWER EXTENSION WEB
TANK TYP
TANK KEEL EXTENSION CAP
Y0.00
TYPICAL AT ALL FUSELAGE FRAMES BETWEEN X1076 AND X1785 BULKHEAD
SCALE 1/20
FRAME CAP
FLEXURE FRAME CAP
PANEL STIFFENER
OVERLAPPING PANEL
FWD
(FULL SCALE)
PAYLOAD COMPARTMENT
FRAME WEB
GH2 PLENUM WALL
GH2 PLENUM SKIN
CAP ANGLE
GOX FRAME WEB
LH2 TANK WL
GOX TANK & MEG
FRAME WEB
FLEXURE FRAME CAP
FRAME CAP
REF PLANE 45° SHEAR WEB
FRAME REF PLANE
(TYPICAL FRAME CONFIG AT Y0.00)
Y4000
(NO SCALE) TYPICAL
REMOVABLE PART OF FRAME FOR TANK REMOVAL
VERTICAL LOAD ONLY
LOAD CAPABILITY ALL DIRECTIONS
STRUT TYPICAL AT ALL PARTIAL FRAMES
SYMMETRY
BLKHD WEB
VERTICAL LOAD ONLY
SIDE LOADS & VERTICAL LOAD
FORE AFT EXPANSION CAPABILITY
SCALE 1/20
WING REF
WING FUSELAGE LINES TYPICAL AT X1425 ALSO
SCALE 1/20
REMOVABLE PART OF BLKHD
BULKHEAD CUT OUT FOR SSME LH2 TANK CLEARANCE
TANK ACCESS DOOR
APS LH2 TANK
TANK DOME FWD
TANK SPT STRUT
BLKHD
VENT LINE
TPS
Z220
TANK
SCALE 1/6
LINK END (TYPICAL)
FRAME FITTING (TYPICAL)
FRAME REF PLANE
ZORBITER
SCALE 1/20
END OF LH2 TANK DOOR
END OF MOLD LINE HOT STRUCTURE
(VIEW ROTATED 90° CW)
SECURITY CLASSIFICATION
DRAWING NUMBER
255BJ30092
SH

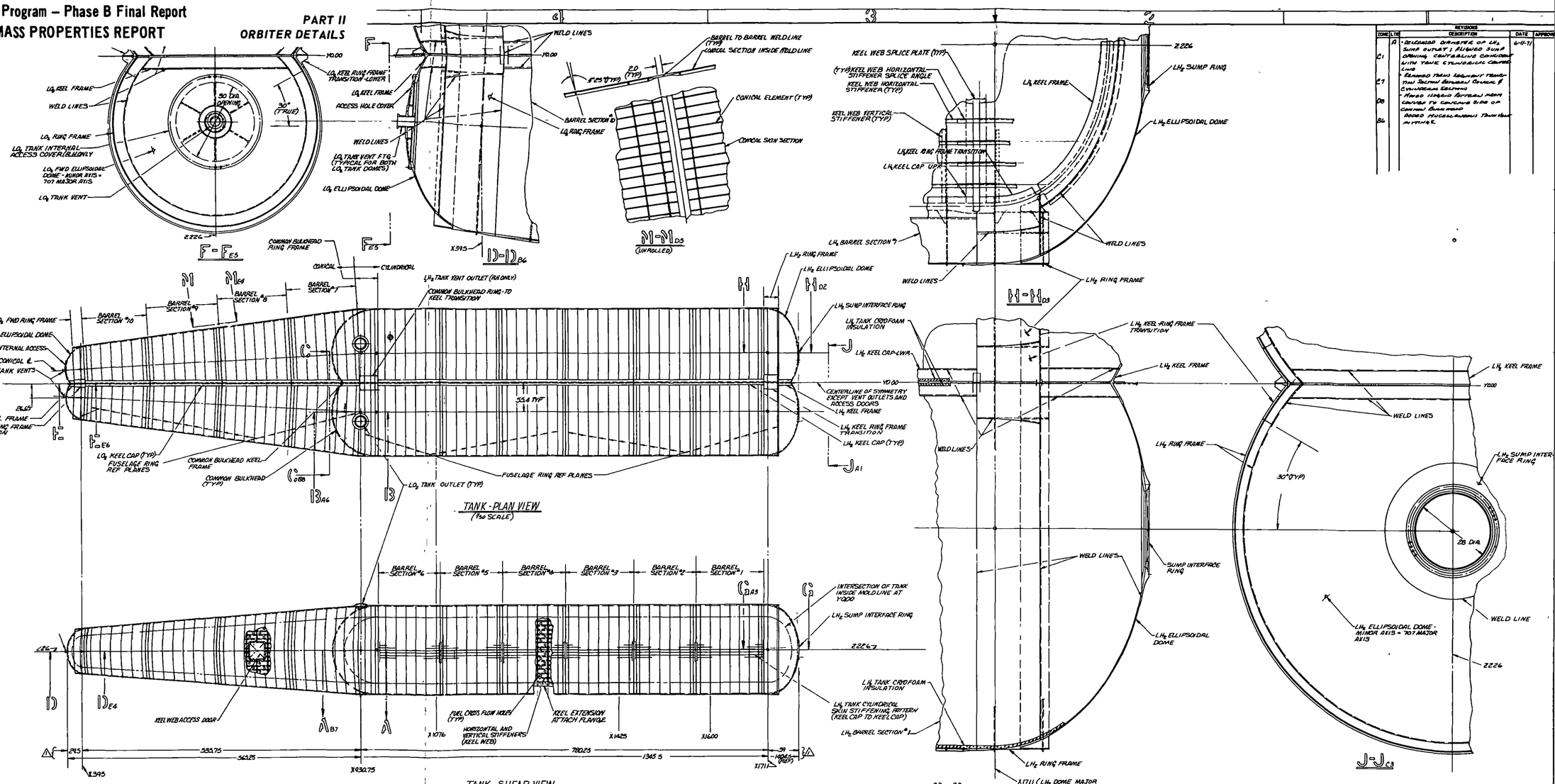

ACPS TANK
ACPS TANK SIDE LOAD STRUT-AFT
X1076 BULKHEAD
FLOOR-AIRLOCK
SUPPORT ARM BACK-UP WEB
AIRLOCK SIDE WALL
℄ PAYLOAD SUPPORT ARM
FLOOR-CABIN
TANK SUPPORT STRUT
X1009
X1076
AIRLOCK PRESSURE WALL
PAYLOAD SUPPORT ARM BRACKET (FAR SIDE)
OPEN FOR TUNNEL
TUNNEL PROTECTIVE SKIN
EOP BLKHD SKIN
ACPS LH2 TANK
ML AT X 1076
ACPS LH TANK SIDE LOAD STRUT AFT
VENT LINE OXIDIZER LINE
℄ORBITER
FWD INTERSTAGE CONNECT
SCALE 1/20
DOOR
SKIN
SCALE 1/4
PT X1081 Z 631, Y 55.6 PAYLOAD DEPLOY (EJT) TRUNNION
WEB
ML X 356
SKIRT SKIN
ML X 232
WELL WEB
WELL (AFT OF X 356)
FRAME
SCALE 1/10
OXIDIZER
TOP OF WELL
PLENUM PAR SIDE (N2 PURGE)
ML X 395
X1076
X277
℄ STRUT
X318
X356
X372
TOP OF WELL
DRAG BRACE ATTACH
SIDE OF WELL
OPEN
OXIDIZER TANK
TANK
TITANIUM SKIRT
INTERCONNECT TANK KEEL EXTENSION
SCALE 1/10
WEB
TOP SIDE WELL
CUT RNG FLG BACK AT GEAR WELL SIDEWALL (SEE SECTION F-F)
SECURITY CLASSIFICATION
DRAWING NUMBER
255BJ30092
X395
X515
REMOVABLE SKIN PANEL
X556
X885
X1009
X1076
DOOR SUPPORT FRAME
X356
TOP EDGE OF SIDE WALL OF WELL
BOTTOM EDGE WELL SIDE WALL
SCALE 1/10
SEE 255BJ35081
X1009
X885
X1076
DOOR EDGE ACPS LH2 TANK
ACPS LH2 TANK
X515
X886
(SEE SECTION 'V-V') ℄ STRUT - LH2 TANK SUPPORT
TOP OF GEAR BAY
KEEL EXTENSION
X277
X318
X356
LOWER ML-ORBITER
FWD INTERSTAGE CONNECT
MAIN PROPULSION TANK SEE 255 BJ58074
X177



REVISIONS			
SYM	ZONE	DESCRIPTION	DATE	APPROVED
A		ADDED B3 GEE WING MODS DELETED ART STRAIN T.P. REVISED BODY FLAP REVISED SPEED BRAKE ADDED TANK RING WEB & SPLICE MODIFIED ACPS LH2 TANK SUPPORT ADDED WING-WING CARRY THRU SPLICE MODIFIED TANK RING - FRAME STRUCTURE ADDED FWD BULKHEAD FOR ACPS LH2 TANK CLEARANCE	4-71 4-71	

DES.		MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EASTERN DIV.	
CHK			
STR			
		MCDONNELL DOUGLAS CORPORATION	
		FUSELAGE STRUCTURAL ASSY - DELTA WING ORBITER	
		SIZE D	CODE IDENT NO. 76701	255BJ30092


WELD LINES
BARREL SECTION #4
WELD LINE
LH2 TANK VENT OUTLET FTG. (DOUBLE CONOSEAL)
VENT FITTING TO BARREL WELD LINE
LO2 KEEL-RING FRAME TRANSITION
LO2 KEEL-RING FRAME TRANSITION (UPPER)
LO2 BARREL SECTION #10
LO2 KEEL FRAME
WELD LINES
Z226
F-F D6
RING TO KEEL TRANSITION
L-L C6
COMMON BULKHEAD KEEL FRAME
CYLINDRICAL BARREL TO RING FRAME WELD LINE
BARREL SECTION #6 SKIN
KEEL CAP TO SKIN WELD LINE
KEEL CAP
RING TO KEEL TRANSITION
Y0.00-7
COMMON BULKHEAD KEEL FRAME
WELD LINES
LH2 TANK CARBOFOAM INSULATION
COMMON BULKHEAD RING FRAME
BARREL SECTION #6 SKIN
WELD LINE-RING FRAME TO TRANSITION
WELD LINE - RING FRAME TO COMMON BULKHEAD
ISOGRID STIFFENERS - COMMON BULKHEAD
30° TYP ABOVE & BELOW Z226
X960.65 Y 55.6 Z 226.0
℄ OF TANK LOBE DIAMETER
X988 Y35.4 Z226.0 ELLIPTICAL ℄ (REF)
X930.75 Y35.4 Z226.0 CONICAL ℄ (REF)
INTERSECTION PLANE BETWEEN RIGHT CYRCULAR CONE AND CYLINDER
12.25 (REF)
145°
61.0 RAD.
WELD LINE
LO2 TANK OUTLET
A8
WELD LINE
60° ABOVE & BELOW Z226
COMMON BULKHEAD (SPHERICAL)
WELD LINES COMMON BULKHEAD PRE-MACHINING
63.15 RAD.
63.0 RAD (REF)
A-A B5
15°(TYP)
100
LH2 TANK VENT OUTLET
LO2 TANK VENTS
LO2 TANK OUTLETS
E7
166 INCH DIA TANK CYLINDRICAL SECTION INSIDE METALLIC ML
Z226
C-C B5
VIEW LOOKING AFT AT COMMON BULKHEAD - RING FRAME CONICAL SECTION DETAIL OMITTED
BARREL SECTION #7
COMMON BULKHEAD RING FRAME
BARREL SECTION #6
LO2 KEEL CAP
LO2 TANK ACCESS COVER
TANK LOOKING AFT (1/50 SCALE)
WELD LINE-COMMON BULKHEAD RING FRAME TO BARREL SECTION #7 SKIN
WELD LINES
LH2 KEEL CAP
RING FRAME TO KEEL TRANSITION
WELD LINE- LO2 TANK OUTLET TO BARREL SECTION #6 SKIN
CONICAL
OUTLET FITTING-LO2 TANK (DOUBLE CORDSEAL)
K-K C8
CYLINDRICAL
COMMON BULKHEAD
B-B C5
COMMON BULKHEAD KEEL FRAME
Z226



ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
	A	• DELETED DIMENSIONS OF LH2 SUMP OUTLET, ALIGNED SUMP OPENING CENTERLINE COINCIDENT WITH TANK CYLINDRICAL CENTER LINE • REVISED TRANS SEQUENCE TRANSITION SECTION BETWEEN CONICAL & CYLINDRICAL SECTIONS • MINOR NUMBER REVISIONS ARISEN CAUSED BY CHANGING SIZE OF COMMON BULKHEAD ADDED MISCELLANEOUS TRIM VENT OPENINGS.	6-11-71	

QTY REQD	QTY REQD FIND NO.	CODE IDENT NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO	NOTE NO	ZONE
				PARTS LIST					

LOFT DATA
LAYOUT NO
TOLERANCE UNLESS NOTED
XX ± .03
XXX ± .010
FINISH
SPEC
CONTR NO
DASH NO | FIN ART QTY REQD | NEXT ASSY | USED ON APPLICATION

DRAWING APPROVALS
STR
STR & MECH
CG-DES

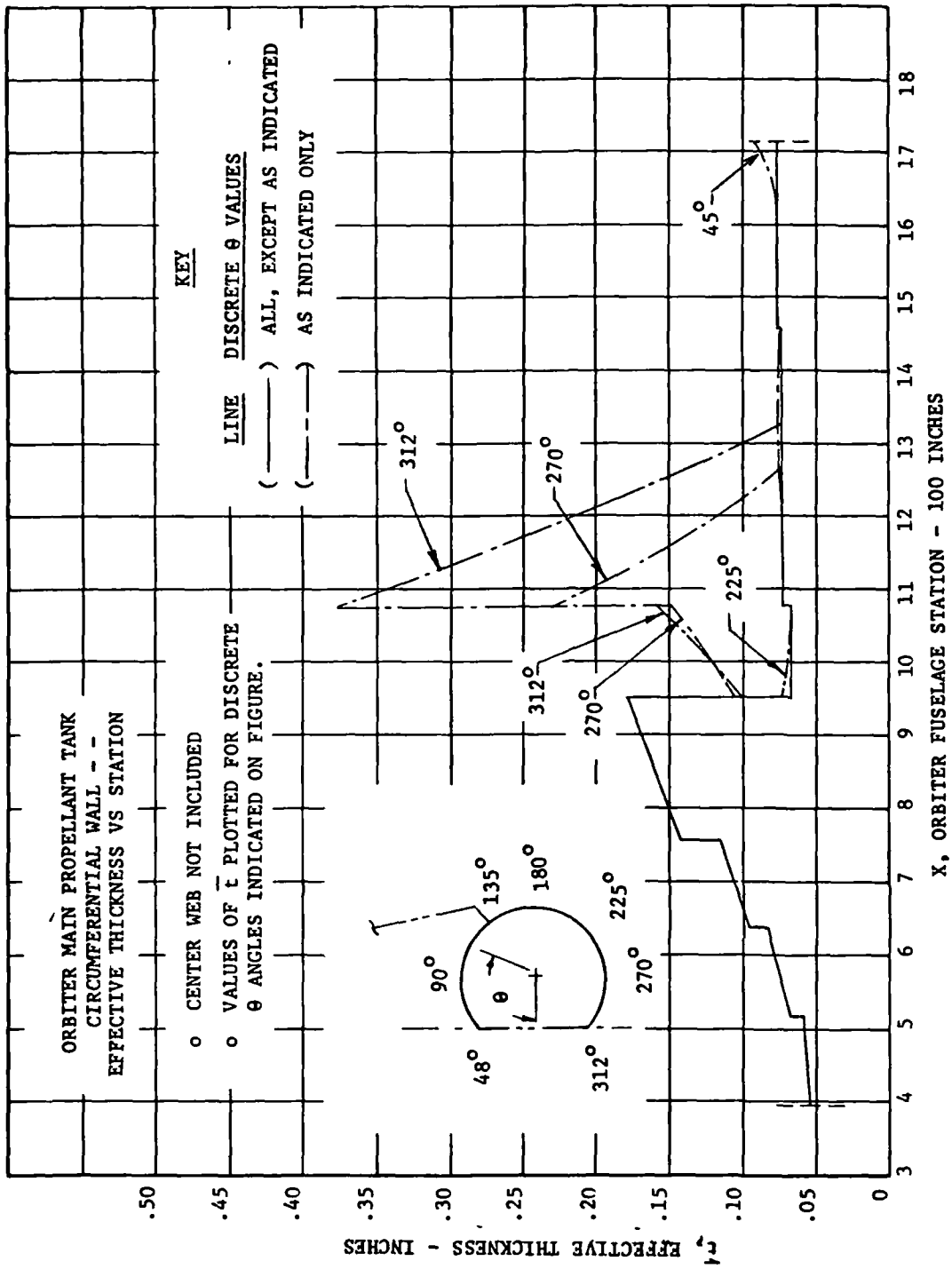
MCDONNELL AIRCRAFT CORPORATION
SAINT LOUIS MISSOURI
MCDONNELL DOUGLAS CORPORATION

TANK ASSEMBLY-MAIN PROPELLANT-DELTA WING ORBITER

SIZE J | CODE IDENT NO 76301 | DRAWING NO 255BJ58074
SCALE 1/50 | WT | SHEET

SECURITY CLASS	DRAWING NUMBER	REV	SH
	255BJ58074	A	

NOTES
⚠ DIMENSIONS FOR THEORETICAL INSIDE MOLD LINE ENVELOPE


ORBITER MAIN PROPELLANT TANK
CIRCUMFERENTIAL WALL - -
EFFECTIVE THICKNESS VS STATION
o CENTER WEB NOT INCLUDED
o VALUES OF t̄ PLOTTED FOR DISCRETE θ ANGLES INDICATED ON FIGURE.
KEY
LINE DISCRETE θ VALUES
(———) ALL, EXCEPT AS INDICATED
(— — —) AS INDICATED ONLY
45°
312°
270°
225°
135°
180°
90°
48°
θ
t̄
$\bar{t}_1$, EFFECTIVE THICKNESS - INCHES
.50
.45
.40
.35
.30
.25
.20
.15
.10
.05
0
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
X, ORBITER FUSELAGE STATION - 100 INCHES

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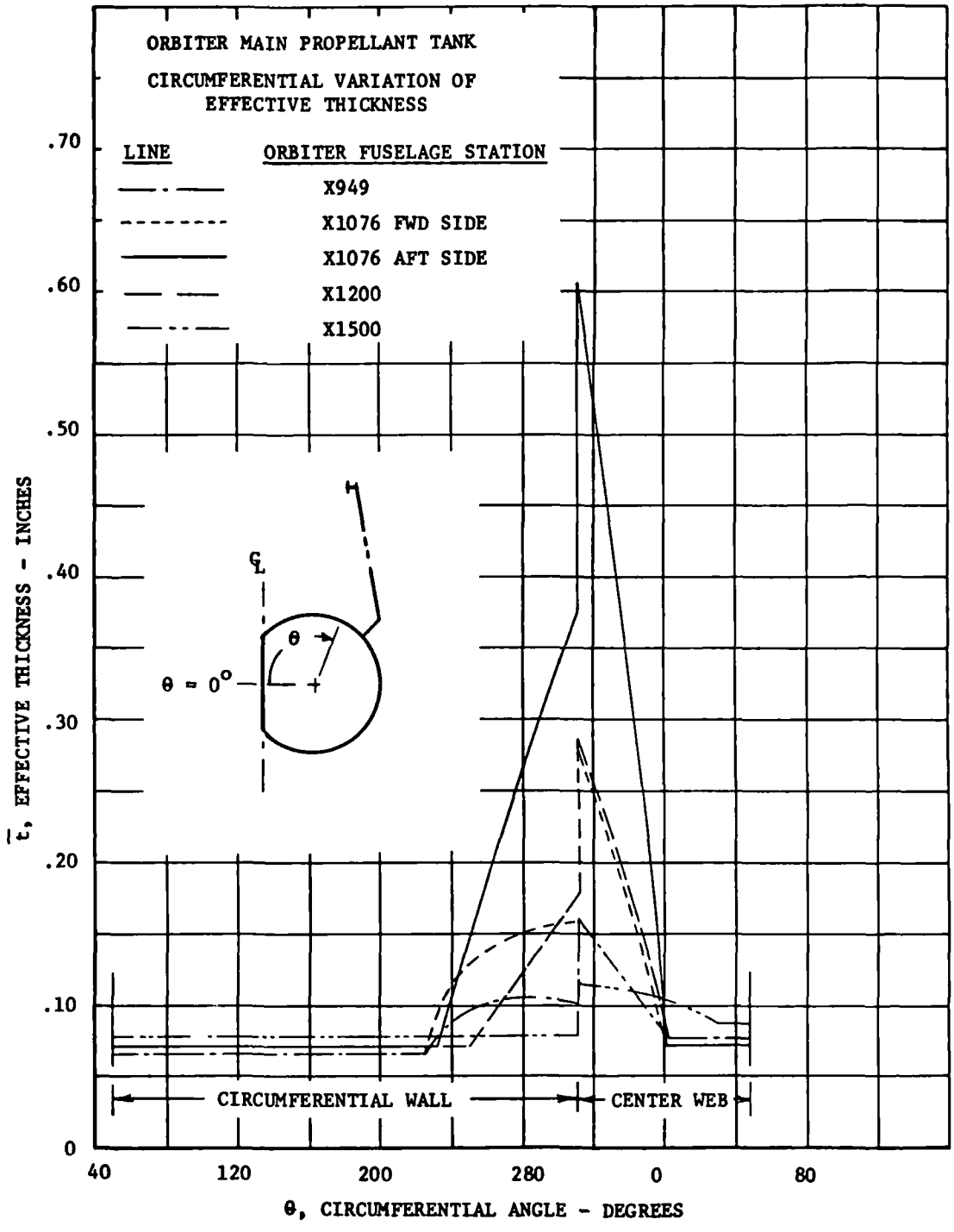
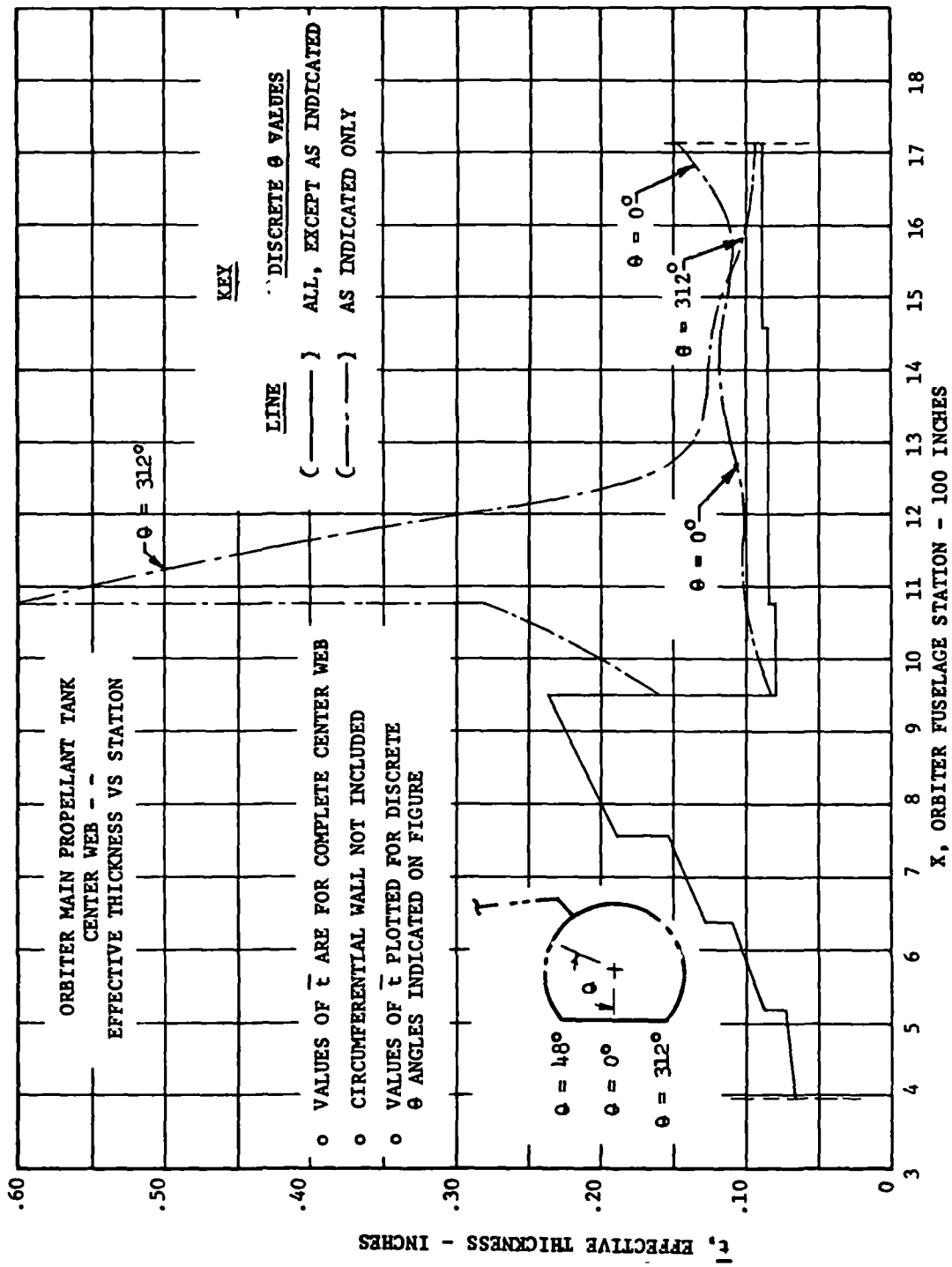
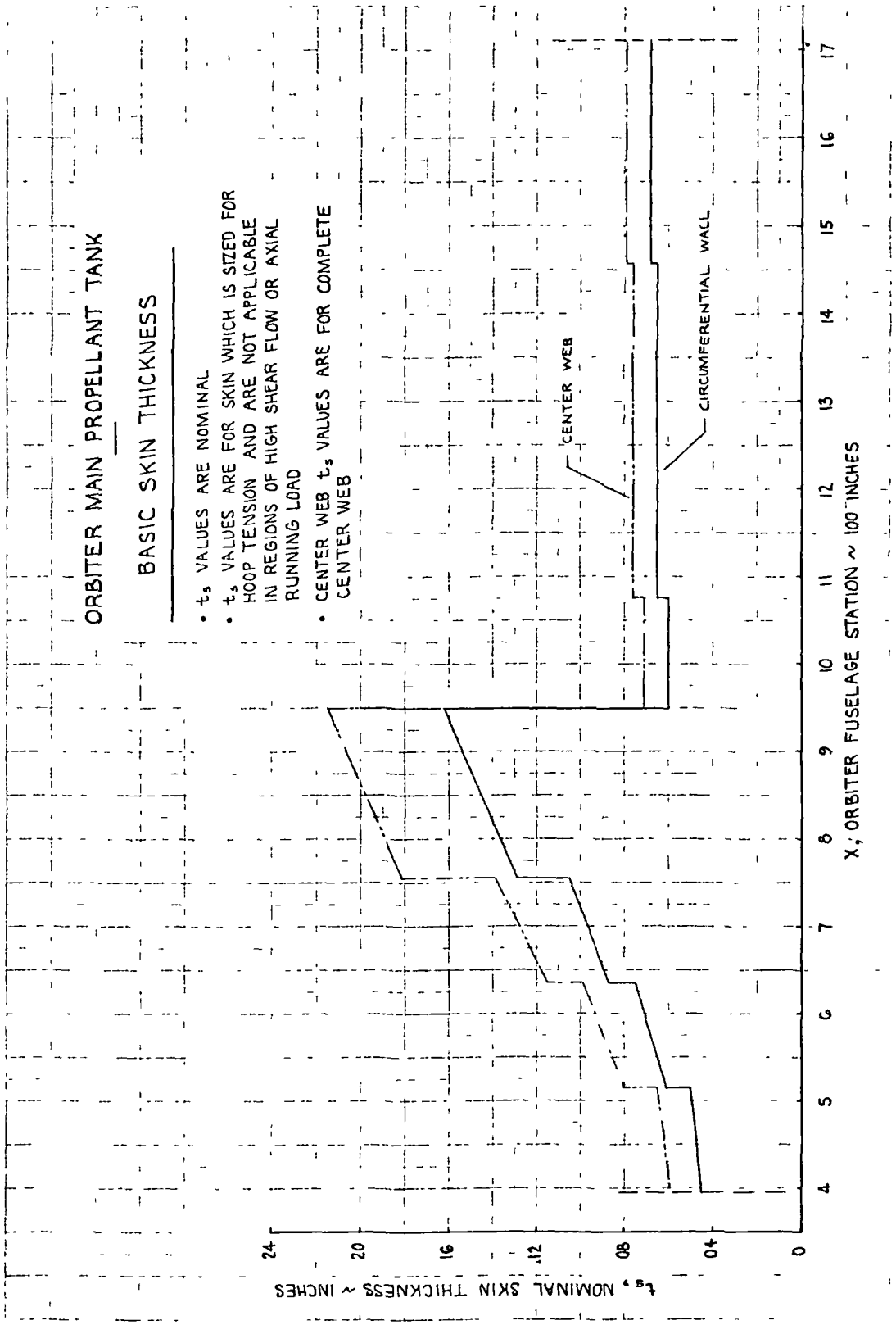


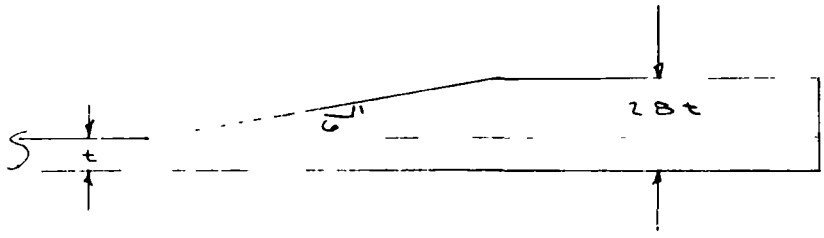

ORBITER MAIN PROPELLANT TANK
CENTER WEB - -
EFFECTIVE THICKNESS VS STATION
KEY
LINE
DISCRETE θ VALUES
ALL, EXCEPT AS INDICATED
AS INDICATED ONLY
o VALUES OF t̄ ARE FOR COMPLETE CENTER WEB
o CIRCUMFERENTIAL WALL NOT INCLUDED
o VALUES OF t̄ PLOTTED FOR DISCRETE θ ANGLES INDICATED ON FIGURE
θ = 312°
θ = 0°
θ = 312°
θ = 0°
θ = 48°
θ = 0°
θ = 312°
t̄, EFFECTIVE THICKNESS - INCHES
.60
.50
.40
.30
.20
.10
0
X, ORBITER FUSELAGE STATION - 100 INCHES
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18


ORBITER MAIN PROPELLANT TANK
BASIC SKIN THICKNESS
• t_s VALUES ARE NOMINAL
• t_s VALUES ARE FOR SKIN WHICH IS SIZED FOR HOOP TENSION AND ARE NOT APPLICABLE IN REGIONS OF HIGH SHEAR FLOW OR AXIAL RUNNING LOAD
• CENTER WEB t_s VALUES ARE FOR COMPLETE CENTER WEB
CENTER WEB
CIRCUMFERENTIAL WALL
t_s, NOMINAL SKIN THICKNESS ~ INCHES
0
04
08
12
16
20
24
X, ORBITER FUSELAGE STATION ~ 100 INCHES
4
5
6
7
8
9
10
11
12
13
14
15
16
17

ORBITER MAIN PROPELLANT TANK
TYPICAL CROSS-SECTIONAL GEOMETRIES

STA	R	t_s	$\bar{t}$	h_F	t_F	b
515	50.	.050	.0575	.400	.04	2.12
635	60	.075	.0825	.582	.04	3.10
755	70.	.105	.1155	.828	.05	3.93
949	83.	.162	.1782	.810	.10	5.00
1076	83.	.060	.0660	.480	.04	3.21
1453	83.	.065	.0715	.536	.04	3.30
1711	83.	.068	.0748	.572	.04	3.36

J GARRISON	BODY	TANK WELDS	



Δ Area = $18t \times 2 + 18t \times 6 \times t \times \frac{1}{2}$

$= 36t + 54t^2$

WELDS @ 120 IN BETWEEN HOOP
@ 380 IN " LONG

ASSUME $t = .1$

$$\frac{(36t + 5.1t^2)(120 + 380)2}{120 \times 380 \times t} = \frac{(36 \times .1 + 5.4 \times .1^2)600 \times 2}{120 \times 380 \times .1}$$

$= 91\%$ FOR FUEL TANK

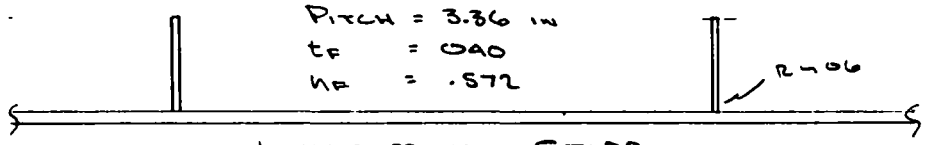
$$\% = \frac{(36t + 5.4t^2)(120 + 276)2}{120 \times 276 \times t} = \frac{(3.6 \times 1 + 5.4 \times .1^2)396 \times 2}{120 \times 276 \times .1}$$

$= 99\%$ FOR LOX TANK

J GARRISON	BODY	LH_2 TANK	1/

STA 1711

t_s : 068
PITCH = 3.36 IN
t_F : 040
h_F : .572



LONGITUDINAL STIFF

$\bar{t} = (068 * 3.36 + 040 * .572) \frac{1}{3.36} = .0748$ IN

RING ATTACH FLANGE

$h_F = 1.0$
$t_f = .068$
PITCH = 20 IN

$\bar{t} = (068 * 20 + 1 * 068) \frac{1}{20} = .0714$ OR 5%

FILLETS

$20 * 2 * (.06)^2 * .2146 = .0309$
$3.36 * 2 * (.06)^2 * .2146 = .0052$
$.6 * 4 * (.38)^2 * .2146 = .0743$
$.1104$ IN^3

$t = \frac{.1104}{20 * 3.36} = .00165$ IN

$\% = \frac{.00165}{.0748} = 2.2\%$

MACHINING

$t \pm .060 \pm .010$ USE .065 OR 8.5%

SUMMARY

HOOK RING	5%
FILLETS	2.2%
MACHINING	8.5%
TOTAL	15.7% NOT INCLUDING WELD

USE FOR ALL LH_2 TANK SECTIONS

LH_2 TANK 2219-T87 2/

AFT BAY FS 1458 TO 1711 R = 83 IN

$\bar{C} = 83 * 2\pi * \frac{264}{360} = 382$ IN

BASIC MAT'L

.075 * 382 * 253 * .102	=	740 LB
RINGS & MANF .157 * 740	=	116 LB
TOTAL		856 LB/SIDE

MIDDLE BAY FS 1075 TO 1458 R = 83 IN

FS 1325 TO 1458 CONSTANT

BASIC MAT'L

.072 * 382 * 133 * .102	=	373 LB
RINGS & MANF .157 * 373	=	59 LB
		432 LB/SIDE

FS 1075 TO 1325

@ 1075 Θ = 312 TO Θ = 233° $\Delta\Theta$ = 79°

$\bar{t}$ = .375 TO $\bar{t}$ = .072

@ 1325 $\bar{t}$ = .072

Θ = 312 TO Θ = 233 $\bar{C} = 83 * 2\pi * \frac{79}{360} = 114$ IN

BASIC MAT'L

INCB 114 * .303 * 250 * ½ * .102	=	440 LB
BASIC 382 * .072 * 250 * .102	=	700 LB
RINGS & MAN'F .157 * 1140	=	179 LB
		1319 LB/SIDE

TOTAL 1751 LB/SIDE

3/

FWD BAY FS 950 TO 1075

BASIC 382 * 066 * 125 * .102 = 322 LB/SIDE

$\theta = 312$ TO $\theta = 232$
$\bar{t} = .158$ TO $\bar{t} = 14$

$\Delta\theta = 80°$ $\bar{c} = 88 * 2\pi * \frac{80}{360} = 116$ IN

INCR = $116 * 125 \left(.092 + .084\right)\frac{1}{2} * .102 = 130$ LB/SIDE

RINGS & MAN'F 452 * .157 = 71 LB/SIDE

TOTAL 523 LB/SIDE

J GARRISON	BODY	LH_2 TANK	1/

CENTER WEB USE SAME NON OPTIMUM AS SHELL

AFT BAY 1711 - 1458

BASIC	124 * 090 * .102 * 253	= 282 LB
BEEF UP	64 * 04 * .102 * 253	= 66 LB
	64 * 04 * .102 * 253	= 66 LB
NON OPT	.157 * 414	= 65 LB
	TOTAL	479 LB

MID BAY 1458 - 1076

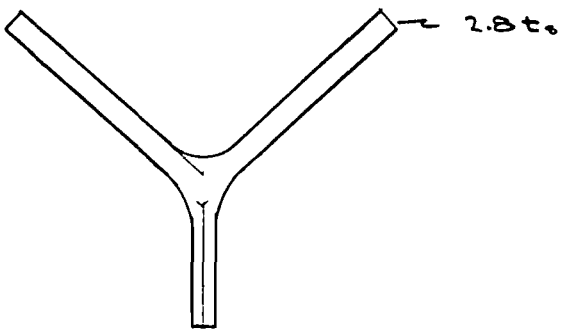
BASIC	124 * 085 * .102 * 392	= 410 LB
BEEF UP	64 * 028 * ½ * .102 * 158	= 15 LB
	64 * 072 * 102 * 158	= 23 LB
	64 * 020 * ½ * .102 * 223	= 29 LB
	64 * 29 * .102 * 223	= 407 LB
NON OPT	.157 * 884	= 139 LB
	TOTAL	1023 LB

FWD BAY

BASIC	124 * 090 * 126 * .102	= 128 LB
BEEF UP	64 * .14 * 126 * .102	= 115 LB
NON OPT	.157 * 243	38 LB
	TOTAL	281 LB

J GARRISON	BODY		

TANK CTR WEB TO SHEW SPLICE



$((3*18t)2 + 15*12t)\,1.15 = 145t$ / SPLICE JOINT

$\frac{14.5}{382} = 4\%$ / SIDE

J GARRISON	BODY	LH_2 TANK	

SUMMARY

SHELL	FWD	2 * 523	= 1046	
	MID	2 * 1751	= 3502	
	AFT	2 * 856	= 1712	
	SUB TOTAL		6260	LB
WELD	091 * 6260		570	LB
Y JOINT	.04 * 6260		250	LB
CENTER WEB	FWD		479	LB
	MID		1023	LB
	AFT		281	LB
TOTAL			8863	LB
			ITEM	13

J GARRISON	BODY	LOX TANK	Y

STA 949 TYPICAL FS 755 TO 950

t_s = .162
PITCH = 8 IN
t_f = .10
h_f = .81

$$\bar{t} = (.162 * 5 + 81 * .1) \frac{1}{5} = .1782$$

FILLETS

$20 * 2 * (.06)^2 * .2146 = .0309$
$5 * 2 * (.04)^2 * .2146 = .0077$
$8 * 4 * (.38)^2 * .2146 = .0992$

.1378

$$t = \frac{.1378}{20 \times 5} = .00138$$

$$\% = \frac{.00138}{.178} = .8\%$$

MACHINING

t = .160 ± 010 USE .165 OR 3%

SUMMARY

HOOP RING	5%
MACHINE	3%
FILLET	.8%
	8.8%

2/

$\bar{c}$ @ 950 & 930 $83 * 2\pi * \frac{264}{360} = 382$ IN

$\bar{c}$ @ 755 $70 * 2\pi * \frac{264}{360} = 322$ IN

FS 950 TO 930

BASIC $382 * .178 * 20 * .102 = 139$ LB

FS 930 TO 755

BASIC $(382+322)\frac{1}{2} * 175 * (178+142)\frac{1}{2} * 102 = 1005$

RINGS & MAN'F - 088A 1144 = 100 LB

TOTAL = 1244 LB/SIDE

3/

STA 755 TYPICAL FS 635 TO 755

$t_B = .105$
PITCH = 3.93
$t_f = .050$
$h_f = .829$

$$\bar{t} = (.105 * 3.93 + .050 * .829) \frac{1}{3.93} = .1155$$

FILLETS
$.70 * 2 * (.06)^2 * .2106 = .0309$
$3.93 * 2 * (.04)^2 * .2106 = .0061$
$.83 * 4 * (.38)^2 * .2106 = .1028$
$.1398$

$$\bar{t} = \frac{.1398}{.70 * 3.93} = .00178 = \frac{1}{4} \quad 1.6\%$$

MACHINING

$.106 \pm .010$ USE $.111$ OR 4.8%

SUMMARY

HOOP RINGS	5%
FILLETS	1.6%
MACHINE	4.8%
	11.4%

$\bar{C}$ @ 755 $= .10 * 2\pi * \frac{264}{360} = 322$ IN

$\bar{C}$ @ 635 $= .60 * 2\pi * \frac{264}{360} = 276$ IN

BASIC $= (322 + 276) \frac{1}{2} * 120 * (.096 + .116) \frac{1}{2} * .102 = 388$ LB

FLANGE & MAN'F $= .114 * 388 = 44$ LB

TOTAL 432 LB/SIDE

4/

STA 635 Typical FS 515 to 635

t_s = 075
pitch = 3.10
h_f = .582
t_f = 040

$\bar{t} = (075 * 3.10 + .582 * 04) \frac{1}{3.10} = .0825$

Fillets

$20 * 2 * (.06)^2 * 2146$	= 0309
$3.1 * 2 * (06)^2 * 2146$	= 0048
$.58 * 4 * (.38)^2 * 2146$	= 0720
	.1077

$t = \frac{1077}{20 * 3.1} = 18\%$

Machining

$t = 072 \pm 010 = 077$ or 7%

Summary

Hoop Ring	5%
Fillets	18%
Machining	7%
	13.8%

$\bar{c}$ @ 635 = $60 * 2\pi * \frac{264}{360} = 276$ in

$\bar{c}$ @ 515 = $50 * 2\pi * \frac{264}{360} = 221.5$ in

Basic = $(276 + 221.5) \frac{1}{2} * 120 * (.082 + .067) \frac{1}{2} * .102 = 227$ LB

Flange & Man'f $.138 * 227 = 31$ LB

Total 258 LB/SIDE

5/

STA 515 TYPICAL FS 395 TO 515

t_s = .050
PITCH = 2.12
h_f = .40
t_f = .04

$\bar{t} = (.050 * 2.12 + .4 * .04) \frac{1}{2.12} = .0575$

FILLETS	$20 * 2 * (.06)^2 * .2146$	= .0309
	$2.12 * 2 * (.06)^2 * .2146$	= .0033
	$.4 * 4 * (.38)^2 * .2146$	= .0496
		.0838

$t = \frac{.0838}{2.12 * 20} = .002 = 3.5\%$

MACHING $t = .045 \pm .010 = .050$ OR 11%

SUMMARY

HOOP RING	5%
MACHING	11%
FILLET	3.5%
	19.5%

$\bar{C}$ @ 515 = $80 * 2\pi * \frac{264}{360} = 221.5$

$\bar{C}$ @ 395 = $41 * 2\pi * \frac{264}{360} = 181$

BASIC $(221 + 181) \frac{1}{2} * 120 * (.058 + .054) \frac{1}{2} * .102 = 138$ LB

FLANGE & MAN'F $.195 * 138 = 27$ LB

TOTAL 165 LB/SIDE

J GARRISON	BODY	LOX TANK

CENTER WEB USE SAME NOW OPTIMUM AS SHELL

STA 950	$\bar{t}$ = .285	h = 124	A = 29.1 IN^2
STA 755 AFT	$\bar{t}$ = 190	h = 104	A = 19.8 IN^2
STA 755 FWD	$\bar{t}$ = .155	h = 104	A = 16.1 IN^2
STA 635 AFT	$\bar{t}$ = .130	h = 90	A = 11.7 IN^2
STA 635 FWD	$\bar{t}$ = .110	h = 90	A = 9.9 IN^2
STA 515 AFT	$\bar{t}$ = .088	h = 75	A = 6.6 IN^2
STA 515 FWD	$\bar{t}$ = 070	h = 75	A = 5.3 IN^2
STA 395	$\bar{t}$ = .065	h = 62	A = 4.0 IN^2

FS 950 - 755
$195\,(29.1 + 19.8)\frac{1}{2} * .102 * 1.088 = 530$ LB

FS 755 - 635
$120(16.1 + 11.7)\frac{1}{2} * .102 * 1.088 = 185$ LB

FS 635 515
$120(9.9 + 6.6)\frac{1}{2} * .102 * 1.088 = 110$ LB

FS 515 - 395
$120(5.3 + 4.0)\frac{1}{2} * .102 * 1.088 = 62$

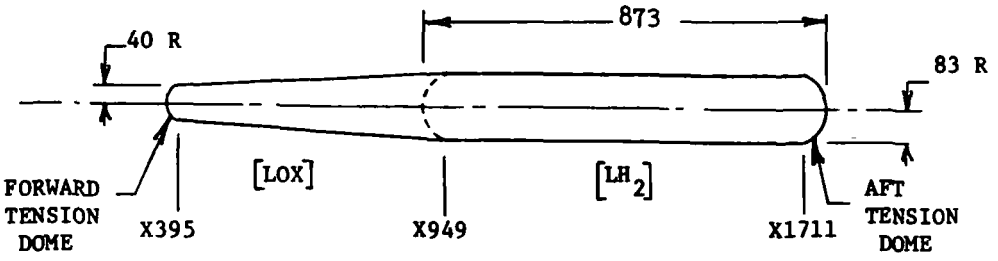
J GARRISON	BODY	LOX TANK	

Summary

SHELL	950 - 755	2 * 1244	=	2488	
	755 - 635	2 * 432	=	864	
	635 - 515	2 * 258	=	516	
	515 - 395	2 * 165	=	330	
	SUB TOTAL			4198	LB
WELD	4198 * 099		=	416	LB
Y JOINT	4198 * .04		=	168	LB
CENTER WEB	950 - 755			530	LB
	755 - 635			185	LB
	635 - 515			110	LB
	515 - 395			62	LB
	TOTAL			5669 LB	

ITEM 6

FWD AND AFT TENSION DOMES



BASIC DOME SKIN THICKNESSES REQUIRED (NOMINAL):

FWD DOME: t_s = .040 INCHES

AFT DOME: t_s = .050 INCHES

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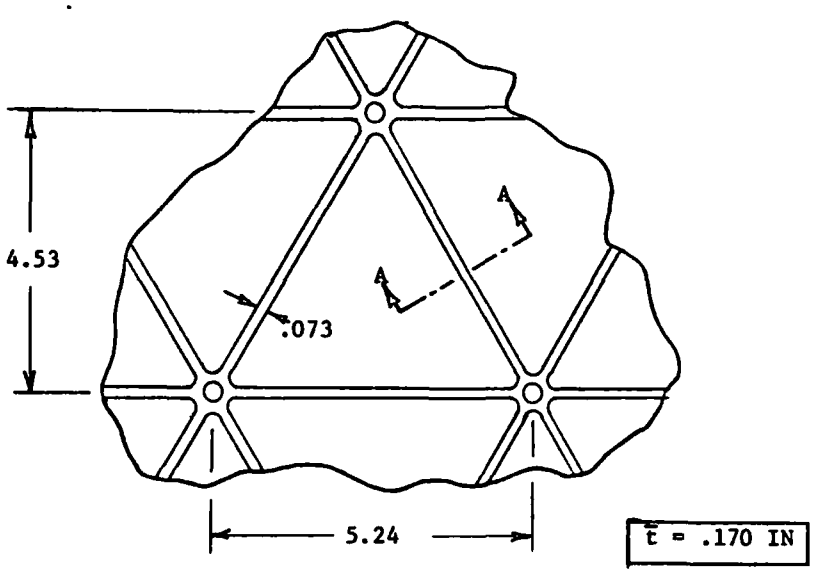
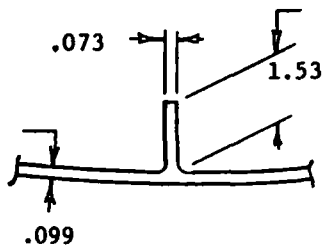
COMMON BULKHEAD DESIGN



VIEW OF BULKHEAD AFT SIDE



VIEW A-A
(ROTATED)

J GARRISON	BODY	AFT LH_2 BKHD	

AREA = $10.2(83 * .707)^2 * 2 = 70200\ IN^2$

BASIC SHELL

$(050 + 003)(70200)\ .102$ = 379 LB

WELD

$.15 * 379$ = 57 LB

SUMP BEEF UP

WT RING = $5(053 * 28^2 \pi/4) 2 * 102$ = 34 LB

ATTACH Y RING

$25 * 470$ = 118 LB

TOTAL 588 LB

ITEM 11

J GARRISON	BODY	FWD LOX BKHD	

Area = $10.2(91 * .707)^2 * 2 = 17200$ in^2

BASIC SHELL

.043 * 17200 * .102 = 76 LB

WELD

.15 * 76 = 11 LB

ACCESS DOOR UP

$10 * 30^2 \pi/4 * .048 * .102$ = 31 LB

ATTACH Y RING

.25 * 118 = 30 LB

TOTAL 148 LB ITEM A

J GARRISON	BODY	COMMON BKHD	

$\bar{t}' = .170 * 1.21$ (ISOGRID NON OPT) $* 1.1$ (MACHINE NON OPT)

$= .226$

BASIC SHELL

$4\pi * 83^2 * .226 * .102 = 2000$ LB

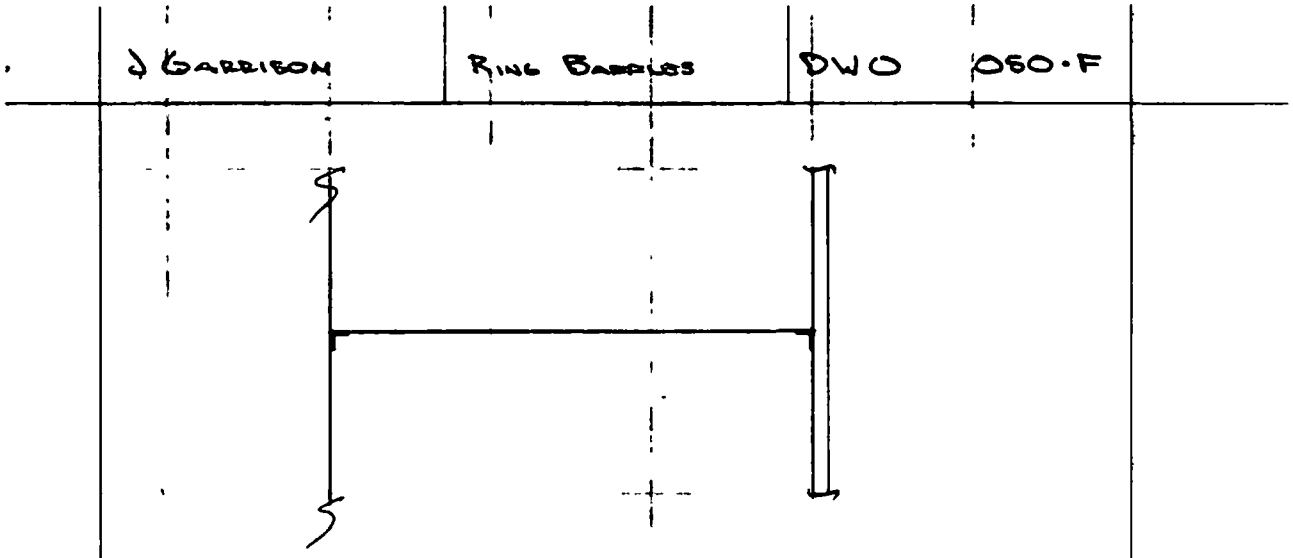
WELD

$.15 * 2000 = 300$ LB

RING

$25 * 2300 = 576$ LB

TOTAL $= 2876$ ITEM 18



OUTER CHORD & INNER CHORD
2×040 = 080 IN²

WEB
30×020 = .6 IN²

TOTAL = .76 IN²
+10% .84 IN²

ASSUME LOX TANK BAFFLES EQUIVALENT TO AN 010 INNER SHELL

S = 224000 IN²
V = 2240 IN³
WT = 2240# .1 ~ 224 LB ITEM 8

ASSUME FUEL TANK BAFFLES EQUIVALENT TO AN 005 INNER SHELL

S = 565000 IN²
V = 2820 IN³
WT = 282 LB ITEM 15

LH_2 TANK INSULATION

C = 92 R

C = 9.2 * 83 = 763 IN

A = 740 * $\frac{763}{144}$ = 3920 FT²

COMMON BKHD = 600 FT²

AFT BKHD = 482 FT²

SUB TOTAL 5002 FT²

CENTER DOME

125 * 740 * 2 * $\frac{1}{144}$ = 1280 FT²

TOTAL 6282 FT²

WT = .180 LINER
.133 FOAM

TOTAL .313 LB/FT²

WT = .313 * 6282 = 1996 LB OR 998 LB/SIDE

ITEM 21

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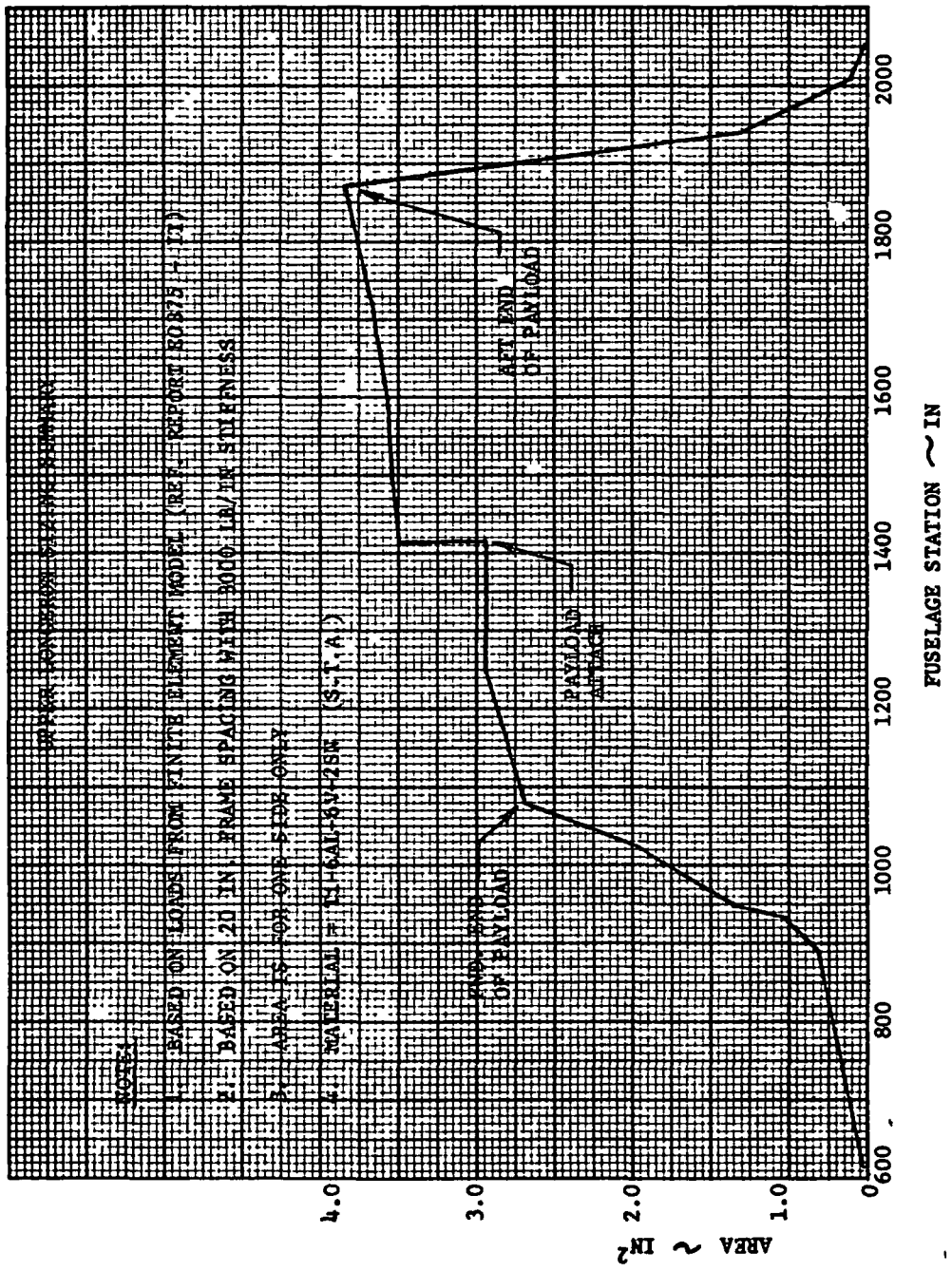
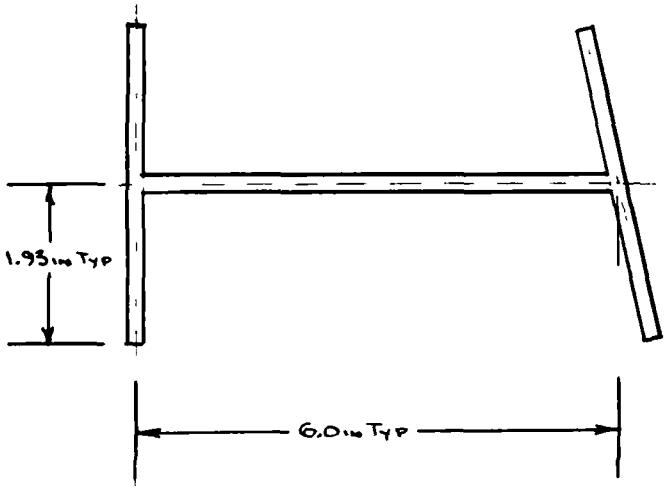


J GARRISON	BODY	LONGERON	1/3

THE BASIC LONGERON SECTION IS AN I EXTRUSION 6" DEEP



THICKNESS VARIES FROM 061 TO 242, DEPENDANT ON THE LOAD

NON OPTIMUM –

ASSUME MILLING TOLERANCE ± 007. ADDING ½ THE UPPER TOLERANCE WILL ADD .0035 OVER THE SURFACE AREA ∽ $(6+4\times1.93).0035 = .05\ in^2$

ADD FILLET RADIUS – TYPICAL R = 125 AFTER MILLING $A = .125^2\pi = .05\ in^2$ FOR 4

TOTAL MAN'R NON OPTIMUM = $.1\ in^2$

ASSUME STRAIGHT LINE TAPERS BETWEEN PEAKS OF AREA PLOT.

ADD 10% OF TOTAL FOR ATTACHMENT & SPLICE ALLOWANCE.

2/3

BASIC LONGERON RUNS OUT AT FS 1937
$A_{REQ} = .84 + .1 = .94\ in^2$

CONSTANT INCREASE TO FS 1865
$A_{REQ} = 3.32 + .1 = 3.42\ in^2$

$\Delta\ Vol = (3.42 + .94)\frac{1}{2} * 72 =$ 157 in^3/SIDE

CONSTANT DECREASE TO FS 1413.
$A_{REQ} = 3.00 + .1 = 3.1$

$\Delta\ Vol = (3.32 + 3.1)\frac{1}{2} * 452 =$ 1450 in^3/SIDE

SECTION CHANGE FWD OF FS 1413
$A_{REQ} = 2.41 + .1 = 2.51\ in^2$

CONSTANT SECTION TO FS 1252
$A_{REQ} = 2.41 + .1 = 2.51\ in^2$

$\Delta Vol = 2.51 * 161 =$ 404 in^3/SIDE

CONSTANT TAPER TO FS 1076
$A_{REQ} = 2.17 + .1 = 2.27$

$\Delta\ Vol = (2.27 + 2.51)\frac{1}{2} * 176 =$ 420 in^3/SIDE

CONSTANT TAPER TO FS 949
$A_{REQ} = .85 + .1 = .95\ in^2$

$\Delta\ Vol = (2.27 + .95)\frac{1}{2} * 127 =$ 220 in^3/SIDE

BASIC LONGERON RUNS OUT AT FS 886
$A_{REQ} = .85 + .1 = .95$

$\Delta Vol = .95 * 63 =$ 60 in^3/SIDE

TOTAL LONGERON VOL/SIDE = 2711 in^3

BASIC WT = 2711 * .160 = 434 LB/SIDE

10% NON OPT FOR ATTACH = 43 LB/SIDE

TOTAL WT/SIDE = 477 LB

NOTE 9 ADD 100 LB/SIDE FOR NONUNIFORM PAYLOAD ATTACH.

FS 1076 - 886	50 LB	
FS 886 FWD	800 LB	
	850 LB/SIDE	ITEM 30
FS 1076 - 1865	427 LB	
NOTE	100 LB	
	527 LB/SIDE	ITEM 39

LONGERON FWD OF BBC

BBC - 615 = 273 IN

AVG AREA = $(.85 + .28)\frac{1}{2} + .1 = .61$ IN^2

W = 273 * .61 * .164 * 1.1 = 300 LB/BIOC

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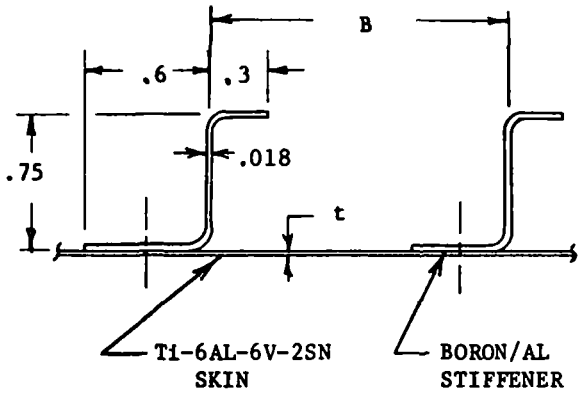
SIDE SHEAR PANEL SIZING SUMMARY



NOTES:

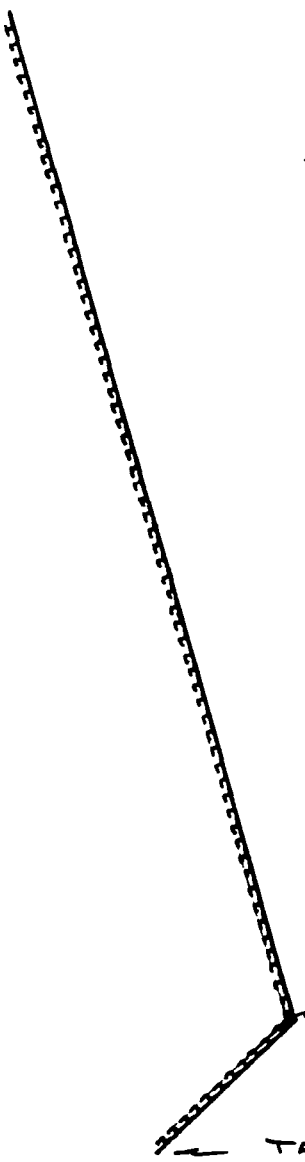
1. LOADS FROM FINITE ELEMENT MODEL OF DELTA WING ORBITER
2. SIZING USING PROGRAM JHDSID WITH THE FOLLOWING CONSTRAINTS:
   a. $t_{min} = .020$
   b. $t_{stiff\ min} = .018$
   c. Min height = .75
   d. Max /b/t = 120
   e. Vent Pressure= 1.4 psi ult.
3. PANELS ARE NON-AXIAL LOAD CARRYING

LOCATION (FUS. STA)	ULT. SHEAR FLOW (LBS/IN)	* CRITICAL COND	B (IN)	t (IN)
615 - 886	690	⑨	2.0	.0223
886 - 929	300	⑩	2.5	.0210
929 - 949	480	⑩	2.0	.0200
949 - 1009	460	⑩	2.0	.0200
1009 - 1076	480	⑩	2.0	.0200
1076 - 1252	200	⑫	2.5	.0208
1252 - 1413	460	⑧	2.0	.0200
1413 - 1593	460	⑧	2.0	.0200
1593 - 1713	550	⑧	2.0	.0206
1713 - 1749	590	⑧	2.0	.0200
1749 - 1785	620	⑧	2.0	.0218
1785 - 1825	730	⑩	2.0	.0227
1825 - 1865	810	⑩	1.5	.0200

* ⑤ = LANDING (MECH)
⑥ = ASCENT THERM
⑦ = LANDING THERM
⑧ = END OF BOOST (MECH. + THERMAL
⑨ = ORB. IG. (MECH. + THERM)
⑩ = MAX αq (MECH. + THERM)
⑪ = MAX βq (MECH. + THERM)
⑫ = LANDING (MECH. + THERM)

J GARRISON	BODY	SHEAR PANEL

TYPICAL PANEL t = .020 STIFF PITCH = 2 IN



TOTAL WEIGHTS	
PANEL	702 LB
STIFFENERS	242 LB
FASTENERS	66 LB
SPLICE ANGLE	18 LB
TANK ATTACH	34 LB
TOTAL	1062 LB/SIDE

J GARRISON	BODY	SHEAR PANELS	1/

BS 613 - 886

PANEL AREA = 273 * (77 + 152) ½ = 31300 IN²

PANEL WT: (022 + 003) 31300 * .164 = 128 LB/SIDE

STIFFENERS

X-SEC = (75 + .3 + .6) .018 = 030 IN²

77/2 = 39 REQ'D @ 613

152/2 = 76 REQ'D @ 886

(76 + 39) ½ * 273 * 030 * .095 = 45 LB/SIDE

FASTENERS

15700 REQ'D @ 00073 = 13 LB/SIDE

ANGLE

040 * 2 * .164 * 273 = 4 LB/SIDE

TANK ATTACH

040 * 4 * .164 * 273 = 7 LB/SIDE

TOTAL = 197 LB/SIDE

2/

BS 886 - 929

PANEL WT = 152 * 43 * (021 + 003) * .164 = 26 LB/SIDE

STIFFENERS

$\frac{152}{2.6}$ = 61 REQ'D

61 * 43 * 030 * .095 = 8 LB/SIDE

FASTENERS

61 * 43 * 00073 = 2 LB/SIDE

ANGLE

040 * 2 * .164 * 43 = .6 LB/SIDE

TANK ATTACH

040 * 4 * .164 * 43 = 1.2 LB/SIDE

TOTAL 37.8 LB/SIDE

BS 929 - 1076

PANEL WT

152 * 147 (020 + 003) * 1.64 = 92 LB/SIDE

STIFFENERS

$\frac{152}{2}$ = 76 REQ'D

76 * 147 * 030 * 095 = 32 LB/SIDE

FASTENERS

76 * 147 * 00073 = 8 LB/SIDE

ANGLE

.0131 * 147 = 2 LB/SIDE

TANK ATTACH

.0262 * 147 = 4 LB/SIDE

TOTAL 138 LB/SIDE

1076 FWD Σ 373 LB ITEM 35

3/

BS 1076 - 1252

PANEL WT
152 * 176 * (.020 + .003) * .164 = 101 LB/SIDE

STIFFENERS
$\frac{152}{2.5} = 61$
61 * 176 * .030 * .095 = 31 LB/SIDE

FASTENERS
61 * 176 * .00073 = 8 LB/SIDE

ANGLE
.0131 * 176 = 2 LB/SIDE

TANK ATTACH
.0262 * 176 = 5 LB/SIDE

TOTAL 147 LB/SIDE

BS 1252 - 1749

PANEL WT
497 * 152 (.020 + .003) * .164 = 285 LB/SIDE

STIFFENERS
$\frac{152}{2} = 76$
76 * 452 * .030 * .095 = 98 LB/SIDE

FASTENERS
497 * 76 * .00073 = 28 LB/SIDE

ANGLE
.0131 * 497 = 7 LB/SIDE

TANK ATTACH
.0252 * 497 = 13 LB/SIDE

TOTAL 431 LB/SIDE

4

BS 1749 - 1825

PANEL WT
76 * 152 * (.022 + .008) * .164 = 47 LB/SIDE

STIFFENERS
QTY = $\frac{152}{2}$ = 76

76 * 76 * .030 * .095 = 16 LB/SIDE

FASTENERS
76 * 76 * .00073 = 4 LB/SIDE

ANGLE
.0131 * 76 = 1 LB/SIDE

TANK ATTACH
.0262 * 76 = 2 LB/SIDE

TOTAL 70 LB/SIDE

BS 1825 - 1865

PANEL WT
40 * 152 * (.020 + .008) * .164 = 23 LB/SIDE

STIFFENERS
QTY = $\frac{152}{1.5}$ = 101

101 * 40 * .030 * .095 = 12 LB/SIDE

FASTENERS
101 * 40 * .00073 = 3 LB/SIDE

ANGLE
.0131 * 40 = 5 LB/SIDE

TANK ATTACH
.0262 * 40 = 1.0 LB/SIDE

TOTAL 39.5 LB

1076 - 1865 Σ 688 LB ITEM 42

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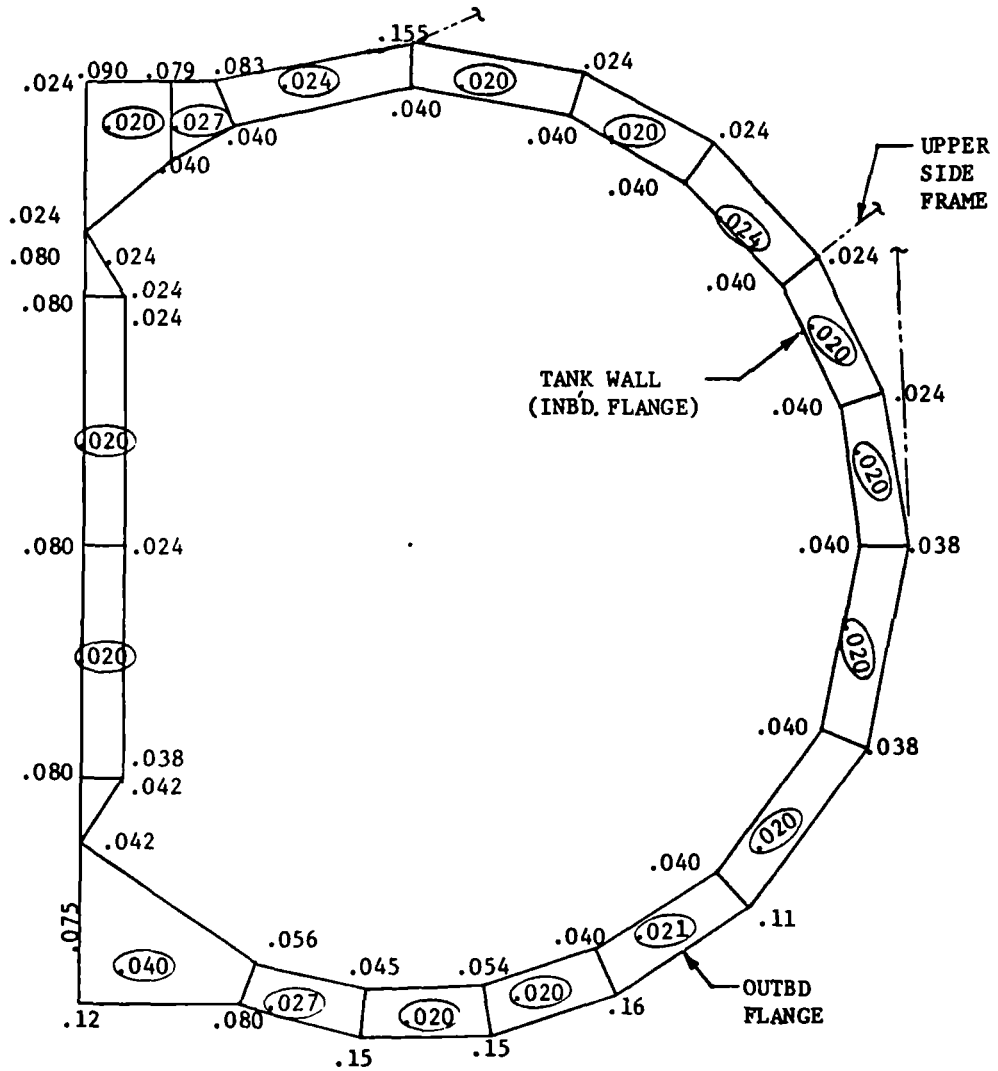
TANK RING SIZING SUMMARY

AVERAGE FOR STATIONS 395 - 1000

NOTES:

1. BASED ON INTERNAL LOADS SHOWN IN REPORT E0375 AS REVISED TO INCORPORATE 5 PSI PRESSURE ON BOTTOM FROM ASCENT INTERFERENCE.
2. CAP AREAS ARE IN "IN^2"; MINIMUM CAP SIZE: OUTBD = .02 x .6 x .6 ANGLE, INBD = .04 x 1.0 TANK FLANGE.
3. OUTBD CAP COLUMN LENGTH ASSUMED TO BE 40" (PROVIDED BY GUSSETS OR STRAPS.)
4. WEB $\bar{t}$ = (XXX) AND INCUDES EFFECT OF LIGHTENING HOLES AND WEB STIFFENERS.
5. MINIMUM WEB THICKNESS = .020



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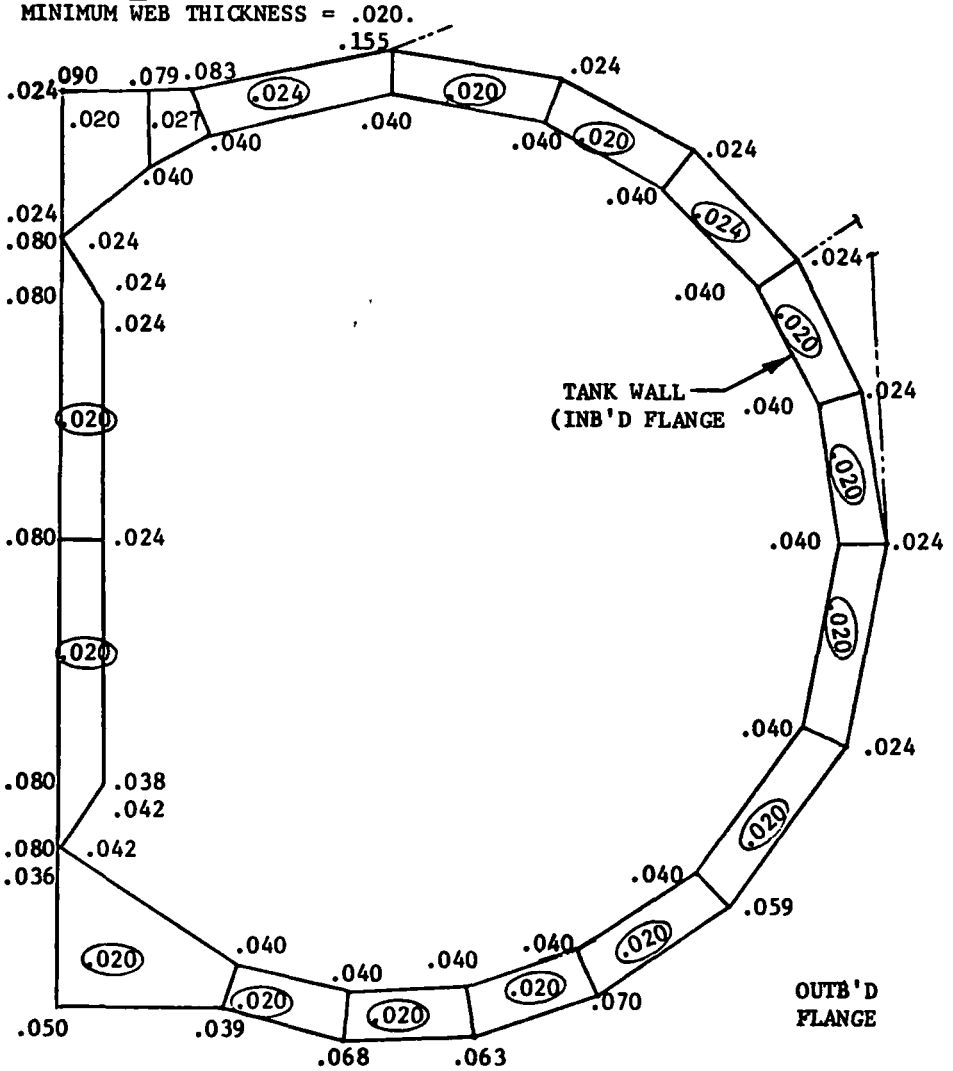
TANK RING SIZING SUMMARY

TYPICAL FOR STATIONS 1000-1713

NOTES:

1. SIZING IS BASED ON INTERNAL LOADS SHOWN IN REPORT E0375 - II.
2. CAP AREAS ARE IN "IN^2"; MINIMUM CAP SIZES : OUTBOARD = .02 x .6 x .6 ANGLE, INBOARD = .05 x 1.0 TANK FLANGE.
3. OUTBOARD CAP COLUMN LENGTHIS ASSUMED TO BE 40" (PROVIDED BY GUSSETS OR STRAPS)
4. WEB t=(XXX) AND INCLUDES EFFECT OF LIGHTENING HOLES AND WEB STIFFENERS.
5. MINIMUM WEB THICKNESS = .020.



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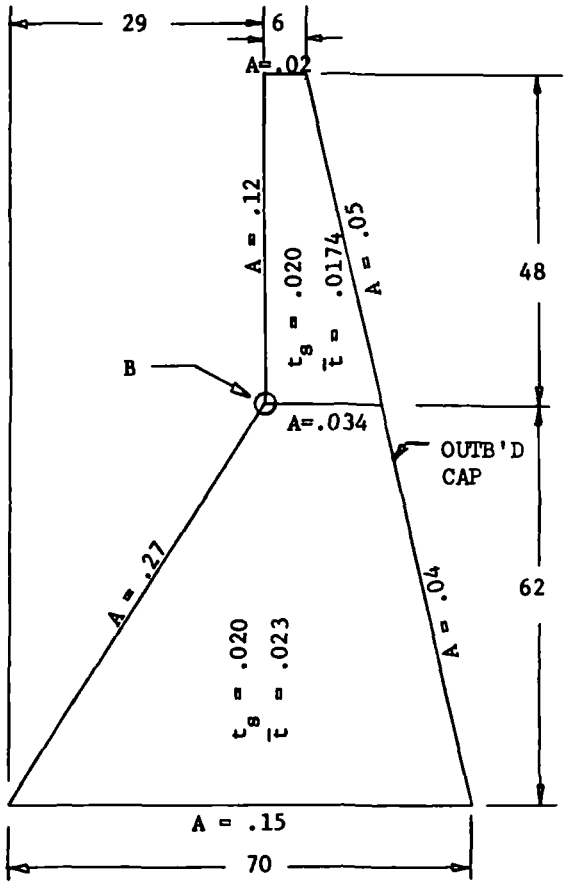
TYPICAL UPPER SIDE FRAME

SIZING SUMMARY

NOTE:

1. BASED ON INTERNAL LOADS SHOWN IN REPORT E0375 VOL. II
2. CAP AREAS ARE IN SQUARE INCHES.
3. WEB THICKNESSES ARE $\bar{t}$ IN INCHES AND INCLUDE EFFECT OF LIGHTENING HOLES AND WEB STIFFENERS
4. LATERAL SUPPORT ASSUMED TO BE PROVIDED AT EACH JOINT (REQUIRES DIAGONAL STRUT AT POINT B)
5. MATERIAL = Ti-6AL-6V-2SN EXCEPT OUTBD CAP = BORON/AL



J GARRISON | BODY | TANK FRAME SUMMARY

STA	TANK RING	FRAME
1845	16	79
1825	16	
1805	16	
1771	31	
1751		
1731		
1711		
1691		
1671		
1651		
1631		
1611		
1571		
1551		
1531		
1511		
1491		
1471		
1451		
1431		
1393		
1373		
1353		
1333		
1313		
1293		
1273		
1253		
1233		
1213		
1193		
1173		
1153		
1133		
1113		
1097	31	79

1071 LB ITEM 49

2844 LB ITEM 47

Σ 1071 LB 2844 LB

1445.648 1460.944

STA	TANK RING	FRAME
1057	31	79
1041		
1025		
1009	31	
985	39	
965		
949		
925		
905		
886	39	79
866	38	78
843	37	77
820	36	76
795	35	75
775	34	74
750	34	73
728	33	72
705	32	70
682	31	69
660	31	68
640	30	67
613	29	66
590	28	1655 LB ITEM 27
565	28	
545	27	
522	26	
500	25	
478	24	
458	24	
435	23	
413	22	
395	21	
	1006 LB ITEM 25	

763,927 854.114

TYPICAL TANK RING

FS 1000 - 1713

Web

BASIC	$86\pi * 2 * 6 * .020 * \frac{264}{360} * .1$	= 4.8 LB/SIDE
BEEF-UP	$40 * 6 * 2 * .1 * .004$	= .2
	SUB TOTAL	= 5 LB/SIDE
NON OPTIMUM	$.28 * 5$	= 1.4
	TOTAL	6.4 LB/SIDE

OUTER CAP

$29.3\ (.050 + .039)\frac{1}{2}$	=	1.31
$29.3\ (.039 + .068)\frac{1}{2}$	=	1.67
$29.3\ (.068 + .063)\frac{1}{2}$	=	1.92
$29.3\ (.063 + .070)\frac{1}{2}$	=	1.93
$29.3\ (.070 + .059)\frac{1}{2}$	=	1.89
$29.3\ (.059 + .024)\frac{1}{2}$	=	1.22
$29.3 * .024 * 5$	=	3.52
$29.3\ (.024 + .155)\frac{1}{2}$	=	2.63
$29.3\ (.155 + .083)\frac{1}{2}$	=	3.49
$29.3\ (.083 + .090)\frac{1}{2}$	=	2.53
Σ	22.03 * .1 * 1.28	= 2.82 LB/SIDE

CENTER WEB

WEB	$6 * 124 * .020 * .1 * 1.28$	= 1.9 LB
CAP	$62 * .024 * .1 * 1.28$	= 1.9 LB
	$62\ (.024 + .040)\frac{1}{2} * .1 * 1.28$	= 2.5 LB
	TOTAL	6.3 LB/SIDE

RING TOTAL 31 LB

UPR SIDE FRAME

UPR WEB

$(6+25)\frac{1}{2} * 48 * .0174 * .164 * 1.28 = 2.7$ LB

CTR WEB

$(28+62)\frac{1}{2} * 60 * .023 * .164 * 1.28 = 13.0$ LB

LWR WEB

$87 * 15 * \frac{1}{2} * .023 * .164 * 1.28 = 3.1$ LB

WEB TOTAL = 188 LB/SIDE

CAPS

$6 * .02 * .164 * 1.28 = .03$ LB

$25 * .034 * .164 * 1.28 = 1.79$ LB

$86 * .15 * .164 * 1.28 = 2.71$ LB

$50 * .12 * .164 * 1.28 = 1.26$ LB

$124 * .27 * .164 * 1.28 = 6.76$ LB

$45 * .050 * .095 * 1.28 = 2.74$ LB

$61 * .040 * .095 * 1.28 = 2.97$ LB

$15 * .040 * .095 * 1.28 = .73$ LB

$18 * .040 * .095 * 1.28 = .88$ LB

CAP TOTAL = 19.9 LB/SIDE

TIE LINK

$26 * .15 * .164 * 1.45 = .9$ LB/SIDE

FRAME TOTAL = 79 LB

TYPICAL TANK RING

FS 395 - 1000

WEB

BASIC $86 \pi * 2 * 6 * .020 * \frac{269}{360} * .1$ = 4.8 LB/SIDE

BEEF UP
- $40 * 6 * 2 * .1 * .009$ = .2 LB/SIDE
- $55 * 20 * \frac{1}{2} * .020 * .1$ = 1.1 LB/SIDE
- $40 * 6 * .020 * .1$ = .5 LB/SIDE
- $40 * 6 * .007 * .1$ = .2 LB/SIDE

SUB TOTAL 6.8 LB/SIDE

NON OPTIMUM $.28 * 6.8$ = 1.9 LB/SIDE

TOTAL 8.7 LB/SIDE

OUTER CAP L = 410 IN ⌐ 14 SEGMENTS

- $29.3 (.12 + .08) \frac{1}{2}$ = 2.93
- $29.3 (.08 + .15) \frac{1}{2}$ = 3.37
- $29.3 (.15)$ = 4.40
- $29.3 (.15 + .16) \frac{1}{2}$ = 4.65
- $29.3 (.16 + .11) \frac{1}{2}$ = 3.95
- $29.3 (.11 + .038) \frac{1}{2}$ = 2.17
- $29.3 (.038)$ = 1.11
- $29.3 (.038 + .024) \frac{1}{2}$ = .91
- $29.3 * .024 * 3$ = 2.11
- $29.3 (.024 + .155)$ = 2.63
- $29.3 (.155 + .083) \frac{1}{2}$ = 3.49
- $29.3 (.083 + .090) \frac{1}{2}$ = 2.54

Σ $34.16 \text{ in}^3 * .1 * 1.28$ = 4.4 LB/SIDE

CTL WEB L = 124

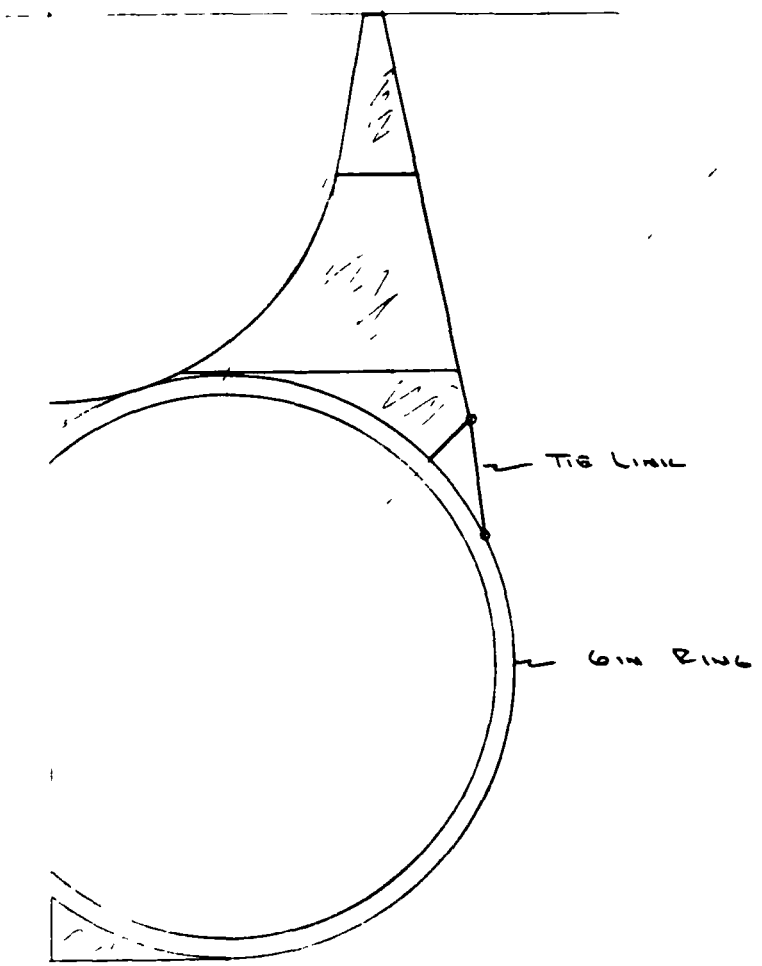
- WEB $= 6 * 124 * .020 * .1 * 1.28$ = 1.9 LB
- CAP $= 62 * .024 * .1 * 1.28$ = 1.9 LB
- $62 (.024 + .040) \frac{1}{2} * .1 * 1.28$ = 2.5 LB

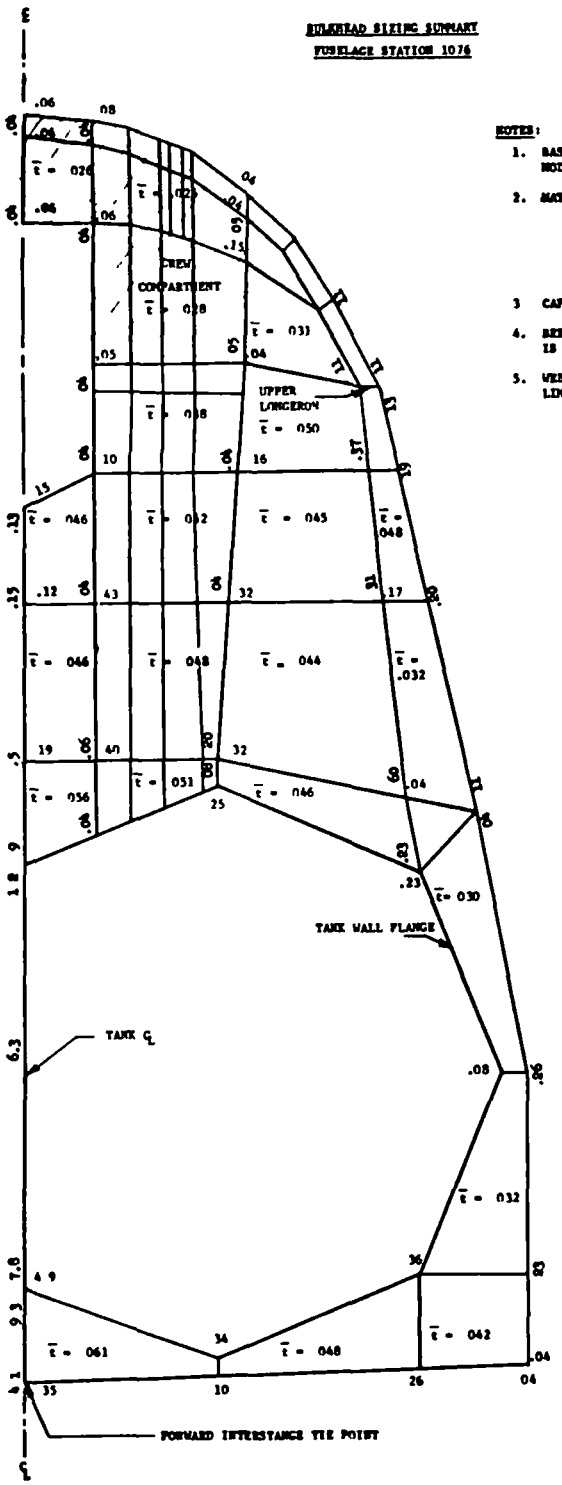
TOTAL 6.3 LB/SIDE

RING TOTAL = 39 LB

J GARRISON	BODY	TANK RING/FRAMES	

GEOMETRY




BULKHEAD SIZING SUMMARY
FUSELAGE STATION 1076
NOTES:
1. BASED ON LOADS FROM FINITE ELEMENT MODEL AS SHOWN ON
2. MATERIAL:
CAP AREAS = BORON/AL
TANK FLANGE = 2219-T87 AL
OTHER = Ti 6AL-6V-2Sn
3 CAP AREAS ARE IN IN 2, WEB t̄ IN INCHES
4. KEEP UP FOR CREW COMPARTMENT PRESSURE IS NOT INCLUDED
5. WEBS SIZED TO BE SHEAR RESISTANT AT LIMIT LOAD (τ/τcr = 2 5)
CREW COMPARTMENT
UPPER LONGERON
TANK WALL FLANGE
TANK ℄
FORWARD INTERSTAGE TIE POINT

J GARRISON	BODY	FS 1076 BKHD	1/

OUTER ML CAP CROWN & DOWN

23 (06+08) ½ * .164	= 0 26
43(.08+.04) ½ * .164	= 0.42
9(04 + .11) ½ * .164	= 0 11
65 * .11 * .164	= 1.17
25 (.13+.13) ½ * 164	= 0 53
51 (.19+.2) ½ * 095	= 0.94
51 (.20+.11) ½ * 095	= 0 75
76 (.04 + .26) ½ * 164	= 1.87
60(.26+.23) ½ * .164	= 2.41
19 (23+04) ½ * .164	= 0.31
19 (04 + 26) ½ * .164	= 0.34
74 (.26+.10) ½ * .164	= 2.18
55 (.10 + 35) ½ * .164	= 2.03
Σ	13.32 LB/SIDE

INNER ML CAP CROWN TO TANK FLANGE

68 *.040 * 164	= 0.45
59 (.04 + .11) ½ * .164	= 0 73
26 (.11 +.37) ½ * .164	= 1.02
50 (37 + 31) ½ * 164	= 2 79
50 (.31 +.60) ½ * .164	= 3 73
30 (6 +.23) ½ * 164	= 2.04
Σ	10.76 LB/SIDE

TANK FLANGE BEEF UP BAB IN L SB IN SEGMENTS

(.9 + 25) ½ * SB * .102	= 3.40
(.25 + 23) ½ * SB * .102	= 1.42
(.23 + .08) ½ * SB * .102	= 0.92
(08 +.30) ½ * SB * .102	= 1 30
(.30 + .34) ½ * SB * .102	= 2 07
(.34 +4.9) ½ * SB * .102	= 15.50
Σ	24.61 LB/SIDE

FS 1076 BKHD 2/

VERTICAL STIFFENERS

℄	30 * 04 * .164	=	0.20
	.19 * 42 * .164	=	0.96
	43 (.15 + .5) ½ * .164	=	2.29
	30 (.5 + .9) ½ * .164	=	3.44
			6.89 LB
BL 23	150 * .04 * .164	=	0.98
	41 (.04 + .04) ½ * .164	=	0.34
			1.32 LB/SIDE
BL 62	050 * 50 * .164	=	0.41
	(.050 + .040) ½ * 32 * .164	=	0.24
	(.040 + .20) ½ * 92 * .164	=	1.81
			2.46 LB/SIDE

HORIZONTAL STIFFENERS

WL 478	06 * 22 * .164	=	0.22
	(.064 .15) ½ * 39 * .164	=	0.67
			0.89 LB/SIDE
WL 425	(.05 + .04) ½ * 40 * .164	=	0.30
	.040 * 40 * .164	=	0.26
			0.56 LB/SIDE
WL 400	(.15 + .10) ½ * 23 * .164	=	0.67
	(.10 + .16) ½ * 42 * .164	=	0.90
	(.164 + .08) ½ * 43 * .164	=	0.85
			2.22 LB/SIDE
WL 350	(.12 + .43) ½ * 23 * .164	=	1.04
	(.43 + .32) ½ * 43 * .164	=	2.64
	(.32 + .17) ½ * 53 * .164	=	2.13
			5.81 LB/SIDE
WL 310	(.14 + .40) ½ * 29 * .164	=	1.11
	(.40 + .32) ½ * 44 * .164	=	2.60
	(.32 + .09) ½ * 60 * .164	=	1.77
			5.48 LB/SIDE

Webs

026 (62)(25) ½ * 164	=	3.30
028 * 40 * 05 * .164	=	8.27
031 * 60 * 28 * ½ * 164	=	4.27
038 * 41 * 31 * .164	=	7.92
050 * 28 * 40 * .164	=	9 18
046 * 22 * 42 * .164	=	6.97
042 * 49 * 42 * .164	=	14.18
045 * 48 * 50 * .164	=	17.71
046 * 46 * 22 * .164	=	7.63
049 * 37 * 44 * .164	=	12.82
044 * 45 * 57 * .164	=	18.51
59 * 6 * 055 * .164	=	3 19
59 * 6 * 046 * .164	=	2.67
59 * 6 * 030 * .164	=	1.74
59 * 6 * 032 * .164	=	1.86
59 * 6 * 048 * .164	=	2 79
59 * 6 * 061 * .164	=	3.54
		126.55 LB/SIDE

Keel Stiffener

64 (1.2 + 6.3) ½ * .100	=	24.00
64 (6.3 + 7.8) ½ * .100	=	45.12
30 (9.3 + 4.1) ½ * . 164	=	32.96
		102.08 LB

Sub Total	=	496 93
* .28	=	139.2
Total		636 LB ITEM 51

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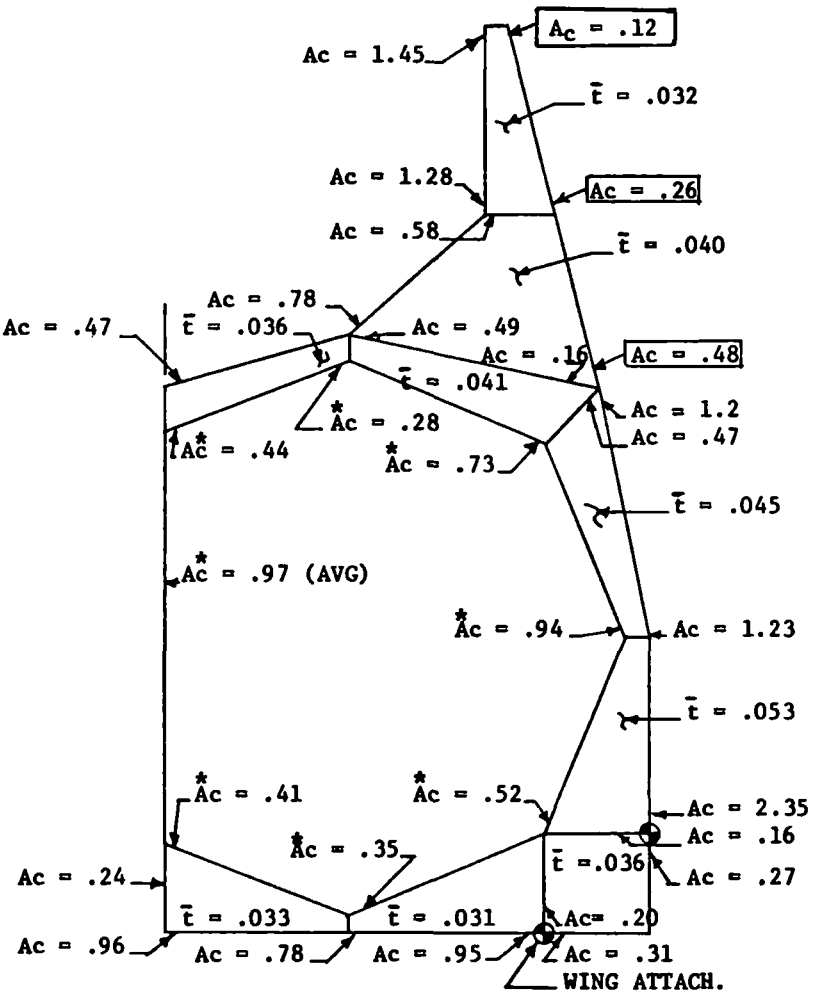
FRAME AT X = 1413

CAP AREAS AND PANEL THICKNESSES

NOTES:

1. A_c = AREA IN SQUARE INCHES
   $\bar{t}$ = UNIT THICKNESS IN INCHES
2. * INDICATES ALUMINUM CAP MATERIAL, BOXED (▭) VALUES ARE BORON-ALUMINUM AND REMAINDER OF CAPS AND WEBS ARE TITANIUM



-71	J GARRISON	BODY	BS 1425 BKHD	1/

UPR SIDE FRAME

UPR WEB
(6+25)½ * 48 * 032 * .164 * 1.28 = 5.3 LB

LWR WEB
(28+62)½ * 60 * 040 * .164 * 1.28 = 22.7 LB

LWR WEB
87 * 15 * ½ * 040 * .164 * 1.28 = 5.5 LB

WEB TOTAL 33.5 LB/SIDE

CAPS

6 * 5 * .164 * 1.28	= .6
25 * .58 * .164 * 1.28	= 3.0
86 * (.49+.16)½ * .164 * 1.28	= 5.9
50 (1.45+1.28)½ * 164 * 1.28	= 14.3
62 (1.28 + 78)½ * .164 * 1.28	= 13.4
62 (78+.47)½ * .164 * 1.28	= 8.1
45 (.12+.29)½ * 164 * 1.28	= 1.9
61 (.29+.98)½ * .164 * 1.28	= 8.1
15 * .07 * .164 * 1.28	= 1.5
18 * .07 * .164 * 1.28	= 1.8

CAP TOTAL 58.6 LB/SIDE

TIE LINK

26 * .07 * 164 * 1.05 = 2.9 LB/SIDE

SUB TOTAL 95 LB/SIDE

2/

LWR RING/BEAMS

WEB $86 * 2\pi * \frac{264}{360} = 397$ IN 6 SEGMENTS

$\frac{397}{6} * 6 = 397$ IN² EACH

036 * 397 * 1.28 * .164	=	3 LB
041 * 397 * 1.28 * .164	=	3.4 LB
045 * 397 * 1.28 * .164	=	3.8 LB
053 * 397 * 1.28 * .164	=	4.4 LB
031 * 397 * 1.28 * .164	=	2.6 LB
033 * 397 * 1.28 * .164	=	2.8 LB

WEB TOTAL = 20 LB/SIDE

OUTER CAP $89 * 2\pi * \frac{264}{360} = 410$ IN

$\frac{410}{6} = 68.3$ IN

$(47 + .49)\frac{1}{2} * 68.3 * 1.28 * .164$	=	6.9 LB
$(.49 + .16)\frac{1}{2} * 68.3 * 1.28 * .164$	=	4.7 LB
$(.16 + 1.23)\frac{1}{2} * 68.3 * 1.28 * .164$	=	10.7 LB
$(1.23 + 2.35)\frac{1}{2} * 68.3 * 1.28 * .164$	=	25.6 LB
$(2.35 + .95)\frac{1}{2} * 68.3 * 1.28 * .164$	=	24.6 LB
$(.95 + .95)\frac{1}{2} * 68.3 * 1.28 * .164$	=	12.9 LB

CAP TOTAL = 85.4 LB/SIDE

INNER FLANGE $83 * 2\pi * \frac{264}{360} = 382$

$\frac{382}{6} = 63.7$ IN

$(.44 + .28)\frac{1}{2} * 63.7 * 1.28 * .102$	=	3.0 LB
$(.28 + .73)\frac{1}{2} * 63.7 * 1.28 * .102$	=	4.2 LB
$(.73 + .94)\frac{1}{2} * 63.7 * 1.28 * .102$	=	7.0 LB
$(.94 + .62)\frac{1}{2} * 63.7 * 1.28 * .102$	=	6.1 LB
$(.62 + .35)\frac{1}{2} * 63.7 * 1.28 * .102$	=	3.6 LB
$(.35 + .41)\frac{1}{2} * 63.7 * 1.28 * .102$	=	3.2 LB

FLANGE TOTAL = 27.1 LB/SIDE

3/

Ctr web

129 * 97 * 1.28 * 102	=	15.7
30 * .24 * 1.28 * .160	=	9
20 * .24 * 1.28 * .160	=	.7
SUB TOTAL		17 3 LB

Total = 472 LB Item 52.5

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

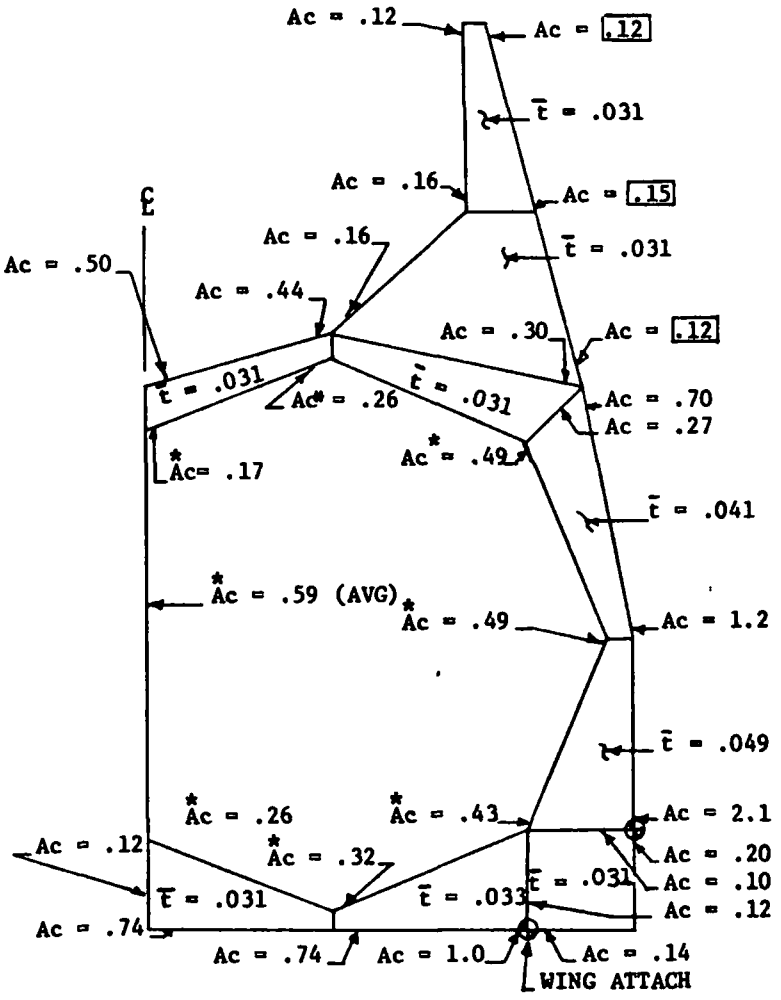
FRAME AT X = 1593

CAP AREAS AND PANEL THICKNESSES

NOTES:

1. Ac = AREA IN SQUARE INCHES
   $\bar{t}$ = UNIT THICKNESS IN INCHES

2. * INDICATES ALUMINUM CAP MATERIAL, BOXED (▭) VALUES ARE BORON-ALUMINUM AND REMAINDER OF CAPS AND WEBS ARE TITANIUM



71	J GARRISON	BODY	BS 1600 FRAME	Y

UPPER SIDE FRAME

UPR WEB
(6+25) ½ * 48 * 031 * .164 * 1.28 = 5.1 LB/SIDE

CTR WEB
(28+62) ½ * 60 * 031 * .164 * 1.28 = 17.6 LB/SIDE

LWR WEB
87 * 15 * ½ * 031 * .164 * 1.28 = 4.8 LB/SIDE

WEB TOTAL 27.0 LB/SIDE

CAPS

6 * 12 * .164 * 1.28	=	.2 LB
25 * 12 * .164 * 1.28	=	.6 LB
86 * .30 * 164 * 1.28	=	5.0 LB
50 * (.12 + 16) ½ * .164 * 1.28	=	1.5 LB
62 * (.16) * .164 * 1.28	=	2.1 LB
62 (.44 + .50) ½ * .164 * 1.28	=	6.1 LB
45 (.12 + .18) ½ * .164 * 1.28	=	1.4 LB
61 (.18 + .43) ½ * .164 * 1.28	=	3.9 LB
15 * .27 * 164 * 1.28	=	.9 LB
18 * .27 * .164 * 1.28	=	1.0 LB

CAP TOTAL = 23.1 LB/SIDE

TIE LINK
26 * 3 * .164 * 1.45 = 1.6 LB/SIDE

SUB TOTAL = 51.7 LB/SIDE

3/

LWR RING / FRAMES

WEB $86 * 2\pi * \frac{264}{360} = 397$ IN 6 SEGMENTS

$\frac{397}{6} * 6 = 397$ IN^2

.031	* 397 * 1.28 * .164	=	2.6 LB
.031	* 397 * 1.28 * .164	=	2.6 LB
.041	* 397 * 1.28 * .164	=	3.4 LB
.049	* 397 * 1.28 * .164	=	4.1 LB
.033	* 397 * 1.28 * .164	=	2.8 LB
.031	* 397 * 1.28 * .164	=	2.6 LB

WEB TOTAL = 18.1 LB/SIDE

OUTER CAP $89 * 2\pi * \frac{264}{360} = 410$ IN

$\frac{410}{6} = 68.3$ IN

(.5 + .44) ½	* 68.3 * .164 * 1.28	=	6.7 LB
(.44 + .30) ½	* 68.3 * .164 * 1.28	=	5.3 LB
(.30 + .12) ½	* 68.3 * .164 * 1.28	=	10.8 LB
(.12 + .21) ½	* 68.3 * .164 * 1.28	=	23.7 LB
(.21 + 1.0) ½	* 68.3 * .164 * 1.28	=	22.2 LB
(1.0 + .74) ½	* 68.3 * .164 * 1.28	=	12.5 LB

CAP TOTAL = 81.2 LB/SIDE

INNER FLANGE $83 * 2\pi * \frac{264}{360} = 382$ IN

$\frac{382}{6} = 63.7$ LB

(.17 + .26) ½	* 63.7 * 1.28 * .102	=	1.8 LB
(.26 + .99) ½	* 63.7 * 1.28 * .102	=	3.1 LB
.99	* 63.7 * 1.28 * .102	=	4.1 LB
(.99 + .43) ½	* 63.7 * 1.28 * .102	=	3.8 LB
(.43 + .32) ½	* 63.7 * 1.28 * .102	=	3.1 LB
(.32 + .26) ½	* 63.7 * 1.28 * .102	=	2.4 LB

FLANGE TOTAL = 18.3 LB/SIDE

3/

Cte Web

124	.59	1.28 .102	= 9.5
30	.12	1.28 .104	= 8
20	.12	1.28 .166	= .5

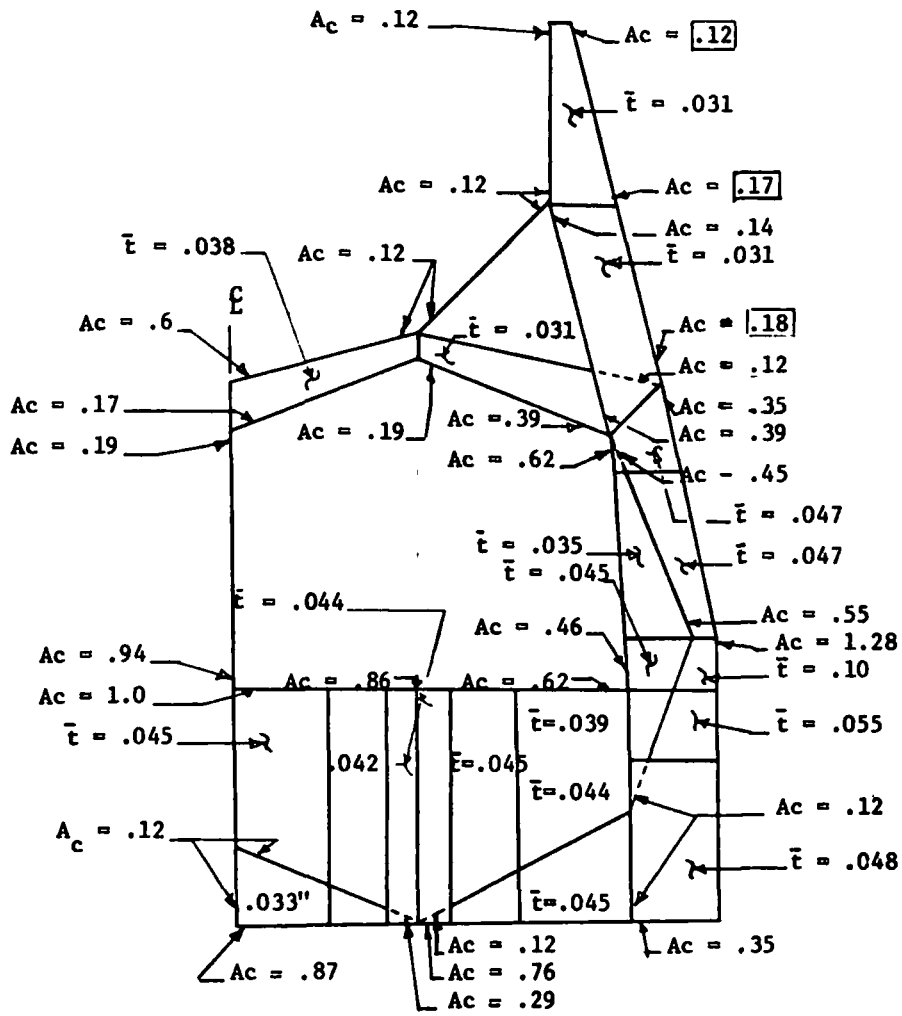
Sub Total = 10.8 lb

Total 349.4 lb Item 52.6

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

FRAME AT X = 1785

CAP AREAS AND PANEL THICKNESSES



NOTE:

1. A_c = AREA IN (INCHES)^2
   "t̄" IS EQUIVALENT THICKNESS OF PANEL PLUS PANEL STIFFENERS IN INCHES.
2. BOXED VALUES (▭) ARE BORON-ALUMINUM CAP AREAS, REMAINDER OF CAPS AND WEBS ARE TITANIUM.

J GARRISON	BODY	1785 BKHD	V

Caps

6 * .12 * 1.28 * .164	= 0.15
5A (.12 + 17) ½ * .095 * 1.28	0.95
57 (.17 + .18) ½ * 095 * 1.28	1.21
56 * .12 * 1.28 * .164	1.41
21 * .12 * 1.28 * .164	0 53
63 (.12 + 39) ½ * 1.28 * .164	3.37
56 * .12 * 1.28 * .164	1.41
76 * .12 * 1.28 * .164	1.91
60 (.12 + .6) ½ * 1.28 * .164	4.53
61 (.17 + .19) ½ * 1.28 * .164	2 30
8 * .12 * 1.28 * .164	0 80
63 (.19 + .39) ½ * 1.28 * .164	3.84
23 * 25 * 1.28 * .164	1.21
79 (.35 + 1.28) ½ * 1.28 * .164	13.52
21 * .36 * 1.28 * .164	1 34
78 (.62 + .40) ½ * 1.28 * .164	8 84
66 (.48 + .65) ½ * 1.28 * .164	6.93
28 * .3 * 1.28 * .164	2 94
12 * 1.28 * 1.28 * .164	3.22
59 (.65 + .12) ½ * 1.28 * .164	4 15
70 (1.28 + 1.35) ½ * 1.28 * .164	19.32
61 (.46 + .12) ½ * 1.28 * .164	3.71
27 (.35) * 1.28 * .164	1 98
27 * .62 * 1.28 * .164	3.51
64 (.62 + .84) ½ * 1.28 * .164	9.94
56 (.80 + 1.0) ½ * 1.28 * .164	10 93
62 (.12 + .29) ½ * 1.28 * .164	2 67
72 (.12) * 1.28 * .164	0 55
56 (.87 + .76) ½ * 1.28 * .164	9.58
65 (.76 + .39) ½ * 1.28 * .164	7 57
27 * .33 * 1.28 * .164	= 1 98
	135.90 LB / S10B

Ctr Cap

94 (.19 + .94) ½ * 1.28 * .164	= 11 15
71 (.94 + .12) ½ * 1.28 * .164	= 7.90
	19.05 LB

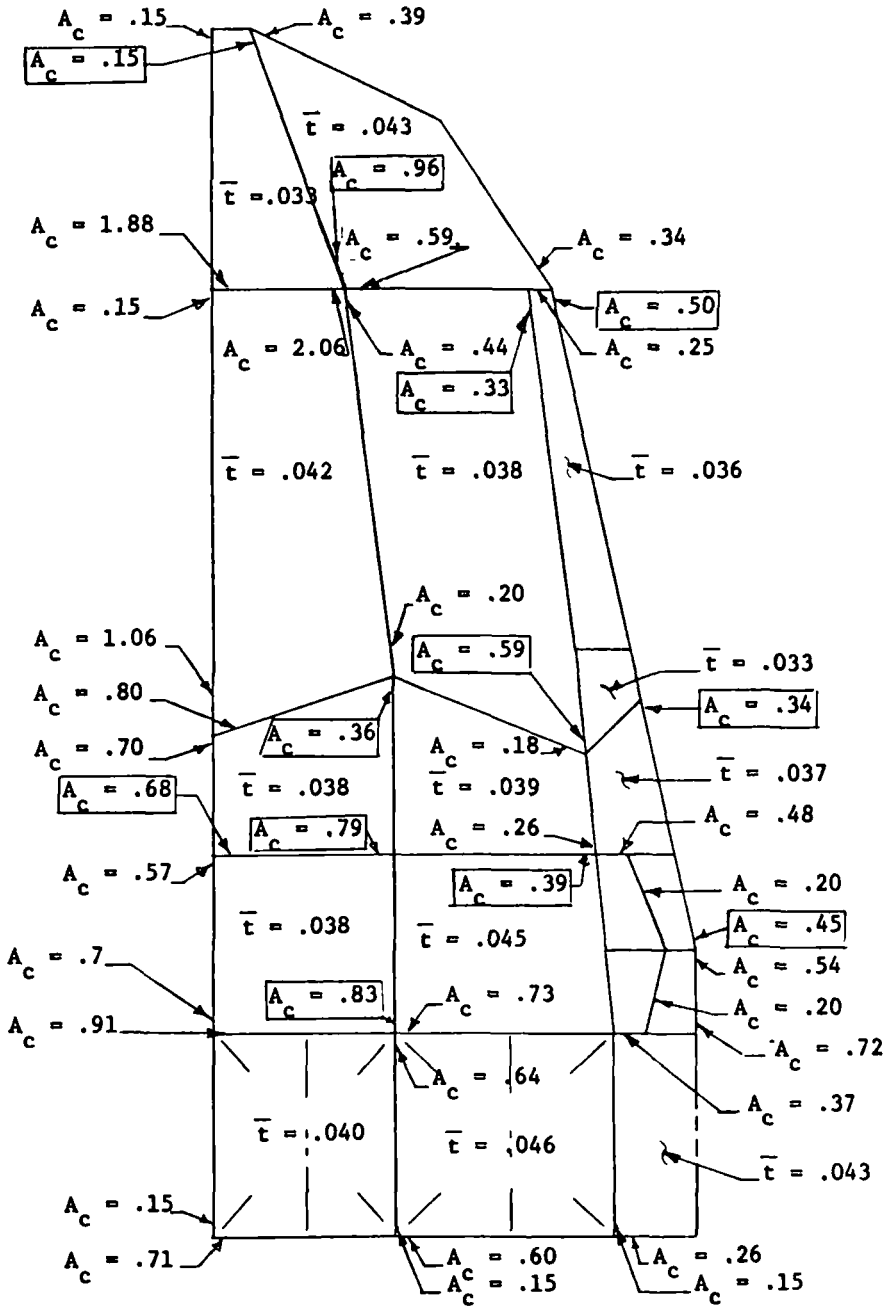
Wees

19 * 56 * 031 * .164 * 1.28	=	5.10
65 * 20 * 031 * .164 * 1.28	=	8.46
56 * 45 * ½ * 031 * .164 * 1.28	=	8.20
61 * 12 * 038 * .164 * 1.28	=	5.84
13 * 57 * 031 * .164 * 1.28	=	4.82
70 * 23 * 047 * .164 * 1.28	=	4.54
27 * 16 * .1 * .164 * 1.28	=	9.07
27 * 21 * 065 * .164 * 1.28	=	6.55
44 * 27 * 048 * .164 * 1.28	=	11.97
65 * 60 * 095 * .164 * 1.28	=	31.17
60 * 20 * 044 * .164 * 1.28	=	11.08
60 * 18 * 042 * .164 * 1.28	=	9.52
60 * 29 * 045 * .164 * 1.28	=	16.44
		132.76 LB/SIDE

TOTAL = 557 LB ITEM 52

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

FRAME AT X = 1865
CAP AREAS AND PANEL THICKNESSES



NOTES: 1. MATERIAL: TITANIUM (Ti 6Al-6V-2Sn)
BORON-ALUMINUM CAPS AS NOTED
2. A_c = CAP AREAS IN SQUARE INCHES
(BOXED VALUES ARE FOR BORON-ALUMINUM)
$\bar{t}$ = UNIT THICKNESSES IN INCHES

1	J GARRISON	BODY	FS 1865 BKHD	1/

ALL MATERIAL 6-6-2 Ti ρ = .164

CAPS

No	L	A_1	A_2	Qty	# WT	
1	139	.39	.34	2	16.6	
2	60	.15	~~.12~~ .96	2	~~10.5~~	6.3
3	77	15	.15	1	1.9	
4	139	.15	1 06	1	13.3	
5	55	1 85	2.06	2	35.3	
6	47	.59	.25	2	6.5	
7	119	.04	.20	2	~~12.1~~	7.2
8	120	~~.15~~ .33	~~.07~~ .59	2	~~23.4~~	12 2
9	130	~~.07~~ .50	~~.25~~ .34	2	~~21.3~~	10.4
10	30	.87	.26	2	5 6	
11	24	.18	~~.34~~ .34	2	~~2.2~~	1.2
12	17	15	.15	2	8	
13	62	.37	.18	2	5.6	
14	60	80	37	2	11.5	
15	54	~~.52~~ .36	~~.93~~ .79	2	~~13.0~~	~~6.7~~ 5.9
16	36	.70	.57	1	3 7	
17	55	~~.04~~ .68	~~.95~~ .79	2	~~16.1~~	7.7
18	54	.57	.70	1	5.6	
19	54	~~.05~~ 79	~~1.07~~ .83	2	~~12.4~~	8 3
20	86	~~.47~~ .79	AB	2	~~20.0~~	10.4
21	54	26	20	2	4.1	
22	31	.20	.20	2	2.0	
23	26	20	20	2	1.7	
24	76	~~.05~~ .34	~~.04~~ 45	2	~~11.0~~	5 7
25	25	~~.54~~ .45	.72	2	~~5.2~~	2.8
26	65	.73	37	2	11.7	
27	56	91	.73	2	15.1	
28	60	.70	.15	4	4.2	
29	60	.64	.15	2	7 8	
30	60	.20	.15	2	3.4	
31	56	.71	60	2	12.0	
32	65	.60	.26	2	9.2	
33	27	.26	.26	2	2.3	
34	27	.37	.37	2	3.3	
35	24	AB	.48	2	3 B	

CAPS ~~243.5~~ LB LD
265.1 LB

FS 1865 BKHD 2/

Webs

ELG	Area	$\bar{t}$	#/SIDE
1	3850	033	20.8
2	2000	043	14.1
3	6800	042	43.4
4	7020	038	43.7
5	1370	036	8.1
6	920	033	2.3
7	2540	039	16 2
8	2530	038	15 8
9	2970	038	18.9
10	3390	043	25 0
11	800	037	4 8
12	3410	040	22.4
13	4220	046	31 8
14	1550	043	10.9
15	1320	043	9 3

287.1 LB/SIDE

CAPS ~~3085~~ 2651
WEB 574.2

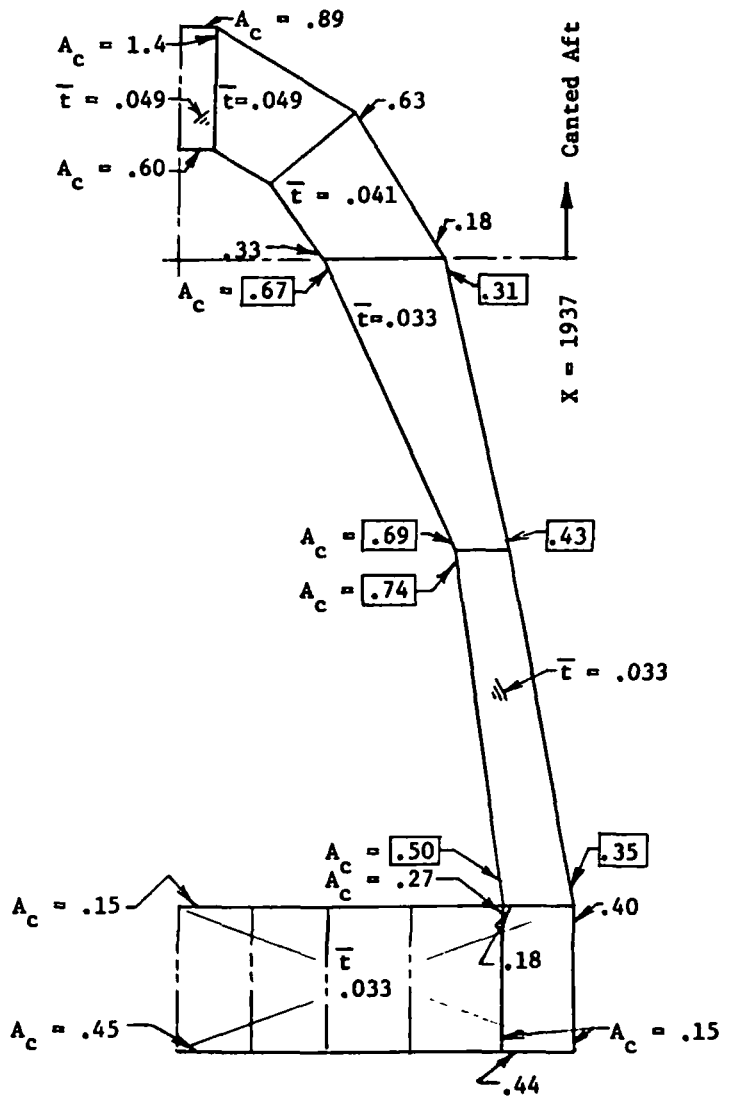
SUBTOTAL ~~9777~~ LB 839.3 LB
28% NON OPT ~~257.4~~ 235.0

~~1175 LB~~ 1074 3 ITEM 57

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

FRAME AT X = 1937
CAP AREAS AND PANEL THICKNESSES

Notes:
1. Material = Titanium (Alloy Ti-6AL-6V-2Sn)
   Boron-Aluminum Caps as noted.
2. A_c = Cap area in in (inches)^2.
   $\bar{t}$ = equivalent thickness of panel plus panel stiffener in inches.
3. Boxed values are Boron-Aluminum cap areas.



J GARRISON	BODY	FS 1937 FRAME	Y

ALL MATERIAL 6-6-2 TI

CANTED PORTION $\frac{1}{\cos 26°} = \frac{1}{.898} = * 1.11$

CAPS

ELEMENT	L	A_1	A_2	Wt	
1	37 * 1.11	1.4	1.4	18.9	
2	18	.89	89	2.9	
3	80 * 1.11	89	.63	13.8	
4	82 * 1.11	63	.18	7.7	
5	90	~~34~~ 31	~~.51~~ .43	~~17.2~~	~~3.2~~ 6.3
6	110	~~.51~~ .43	~~.40~~ .35	~~16.4~~	8.2
7	~~48~~	.40	.15	4.0	
8	122	.25	.44	19.8	
9	~~88~~	~~.75~~ .27	.15	~~8.5~~	~~1.5~~ 3.0
10	122	.15	.18	6.6	
11	188	~~.25~~ .50	~~.74~~ .74	~~30.8~~	12.7
12	98	~~.89~~ .69	~~.98~~ .67	~~30.7~~	12.7
13	17	~~.96~~ .69	~~.51~~ .43	~~4.6~~	1.8
14	39	.33	.33	4.0	
15	~~48~~ 33 * 1.21	.33	.60	8.1	
16	33 * 1.21	.60	60	7.2	
17	18	60	60	2.0	

SUB TOTAL ~~194.8~~ LB 139.7

WEBS

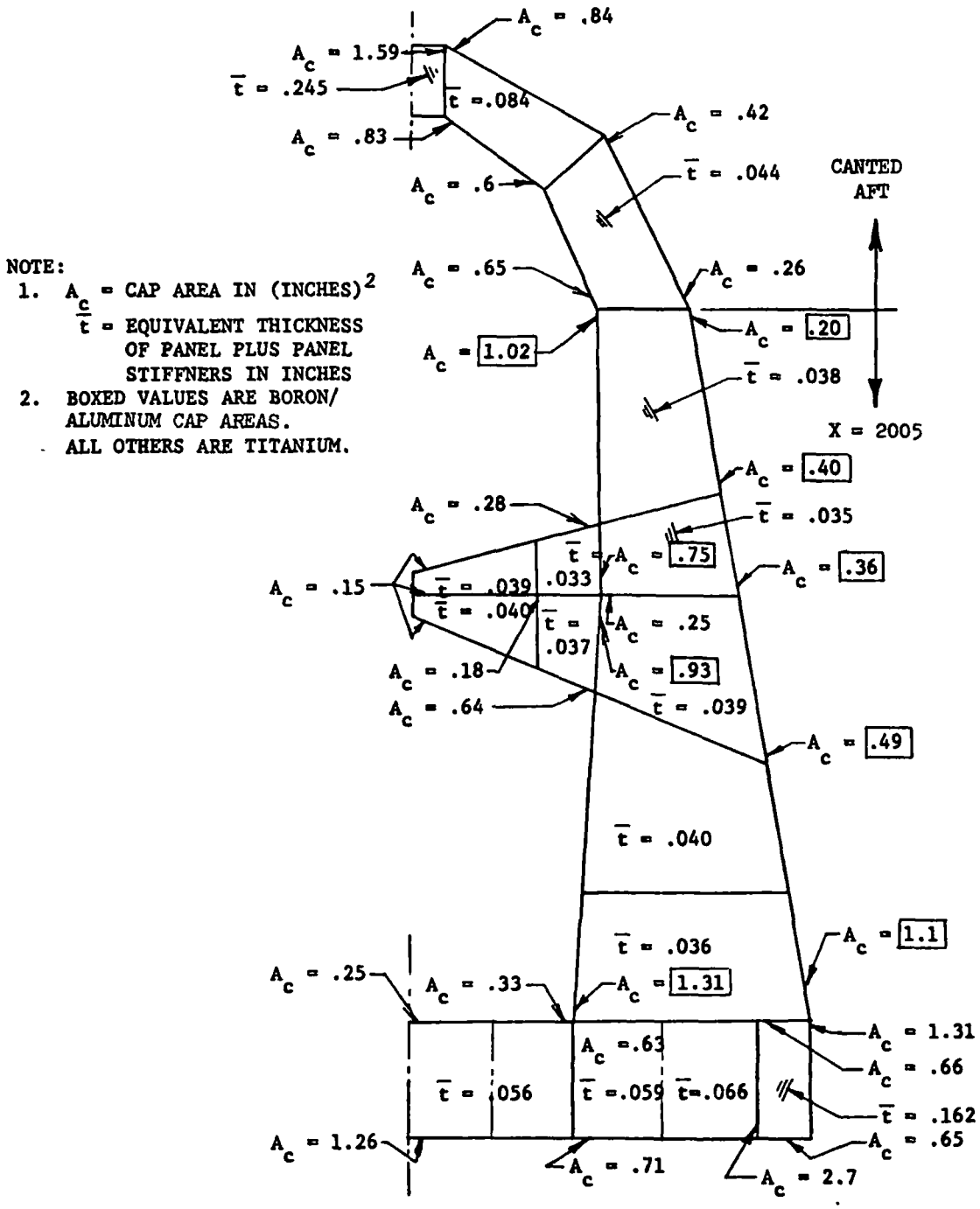
ELE	AREA	$\bar{t}$	Wt/SIDE
1	880	094	6.9
2	1500	049	12.1
3	1610	091	10.8
4	2550	033	13.8
5	2180	033	11.8
6	5250	033	28.4

SUB TOTAL 83.8 LB/SIDE

CAPS	~~195~~	140
WEB	168	
20%	~~308~~	86
	~~503.0~~	394 LB

ITEM 57.5

FRAME AT X = 2005
CAP AREAS AND WEB THICKNESS



NOTE:
1. A_c = CAP AREA IN (INCHES)^2
   $\bar{t}$ = EQUIVALENT THICKNESS OF PANEL PLUS PANEL STIFFNERS IN INCHES
2. BOXED VALUES ARE BORON/ ALUMINUM CAP AREAS.
   ALL OTHERS ARE TITANIUM.

J GARRISON	BODY	FS 2009 FRAMS	Y

ALL MATERIAL 6-6-2 Ti

CANTED PORTION $* \frac{1}{\cos 21^\circ} = * 1.07$

CAPS

ELEMENT	L	A_1	A_2	QTY	Σ WT	
1	12	.84	.84	2	33	
2	25 *1.07	1.59	1.59		14.0	
3	65 *1.07	84	.42		14.4	
4	28	42	42		3 9	
5	66 *1.07	.42	.26		7 8	
6	32	.26	.26		2.7	
7	65	~~.25~~ .30	~~.47~~ .40		~~2.5~~	3.7
8	41	.28	~~.44~~ .40		~~5.1~~	2 8
9	36	~~.47~~ .40	~~.47~~ 36		~~5.2~~	2 6
10	48	25	.25		3 9	
11	58	~~.47~~ 36	~~.54~~ .49		~~9.3~~	4 7
12	65	64	~~.59~~ .49		~~13.1~~	7.0
13	90	~~.89~~ .49	~~1.37~~ 1.1		~~25.0~~	13.6
14	72	.80	80		18.9	
15	40	66	2.7		22 0	
16	18	65	65		3.8	
17	64	.71	65		14 3	
18	59	1 26	.71		18.7	
19	58	.25	.33		5 5	
20	148	~~1.75~~ 1.31	~~1.13~~ 93		~~24.0~~	31 5
21	70	.15	.64		9.1	
22	45	18	.18		2 6	
23	66	15	.25		4.3	
24	68	.15	28		4.8	
25	75	~~.47~~ .75	~~1.09~~ 1.02		~~27.8~~	12 6
26	46 *1.07	.65	60		10.1	
27	43 *1.07	.60	83		10 8	
28	13	.83	.83		3.5	
29	82	33	.66	2	13 3	

SUB TOTAL ~~368.2~~ LB
270 2 LB

FS 2005 FRAME 2/

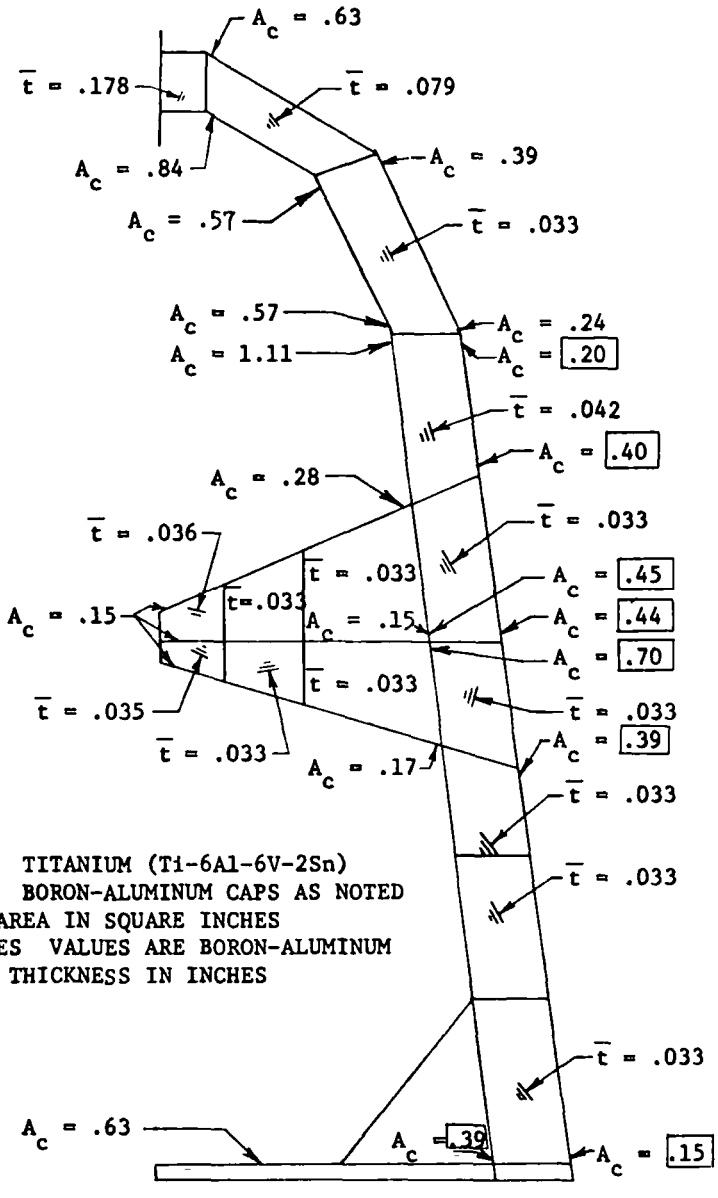
WEB

ELEMENT	AREA	t	WT/SIDE
1	330	245	13.3
2	1390	.084	19.1
3	1680	044	12.1
4	2660	038	16.6
5	1350	.035	7.7
6	1180	.039	7.5
7	3830	.040	25.1
8	3310	.036	19.5
9	720	.162	19.1
10	1360	.066	14.7
11	1200	.059	11.6
12	2520	.056	21.3
13	610	.037	3.7
14	440	.033	2.4
15	570	.039	3.6
16	600	.040	3.9
		SUB TOTAL	201.2

CAPS ~~301~~ 270 @
WEB 201
20% ~~150~~ 132

~~721~~ LB 603 LB ITEM 58

FRAME AT X = 2049
CAP AREAS AND PANEL THICKNESS



NOTES:

1. MATERIAL: TITANIUM (Ti-6Al-6V-2Sn)
   BORON-ALUMINUM CAPS AS NOTED
2. A_c = CAP AREA IN SQUARE INCHES
   BOXES VALUES ARE BORON-ALUMINUM
   $\bar{t}$ = UNIT THICKNESS IN INCHES

J GARRISON	BODY	FS 2049 FRAME	Y

ALL MATERIAL 6-6-2 Ti

CAPS

ELEMENT	L	A_1	A_2	QTY	EWT	
1	14	.63	.63	2	2.9	
2	60	.63	.39		10.0	
3	60	.39	.24		6.2	
4	43	~~.24~~ .20	~~.48~~ .40		~~5.1~~	2.5
5	50	~~.48~~ .40	~~.53~~ .44		~~8.3~~	4.0
6	39	~~.53~~ .44	~~.05~~ .39		~~6.2~~	3.1
7	121	~~.05~~ .39	.15		~~4.4~~	6.2
8	23	.63	.63		4.8	
9	109	.63	.63		21.3	
10	65	.15	.15		3.2	
11	159	~~.106~~ .70	~~.75~~ .39		~~9.6~~	16.5
12	23	.15	.15		1.1	
13	23	.15	.15		1.1	
14	24	.17	~~.24~~ .39		~~2.4~~	1.3
15	90	.15	.17		4.7	
16	83	.15	.15		4.1	
17	84	.15	.29		5.9	
18	30	.15	.15		1.5	
19	93	1.11	~~.62~~ .45		~~20.4~~	13.8
20	22	~~.62~~ .45	~~.53~~ .44		~~4.1~~	1.9
21	23	.28	~~.28~~ .40		~~2.9~~	1.5
22	21	.57	.24		2.8	
23	53	.57	.57		9.9	
24	19	.15	.15		.9	
25	39	.84	.57		9.0	
26	19	.84	.84		3.8	
27	18	.63	.84	2	4.3	

SUB TOTAL ~~196.3~~ 148.3

FS 2049 FRAME 2/

WEB

ELEMENT	AREA	$\bar{t}$	WT/SIDE
1	340	.178	7.9
2	750	.079	9.7
3	1100	.033	6.0
4	990	042	6.8
5	1010	.033	5.5
6	750	.033	4.1
7	570	.033	3.1
8	970	.033	5.2
9	1150	.033	6.2
10	810	033	4.4
11	1000	.033	5.4
12	1260	.033	6.8
13	1320	.033	7.1
		SUB TOTAL	80.2 LB/SIDE

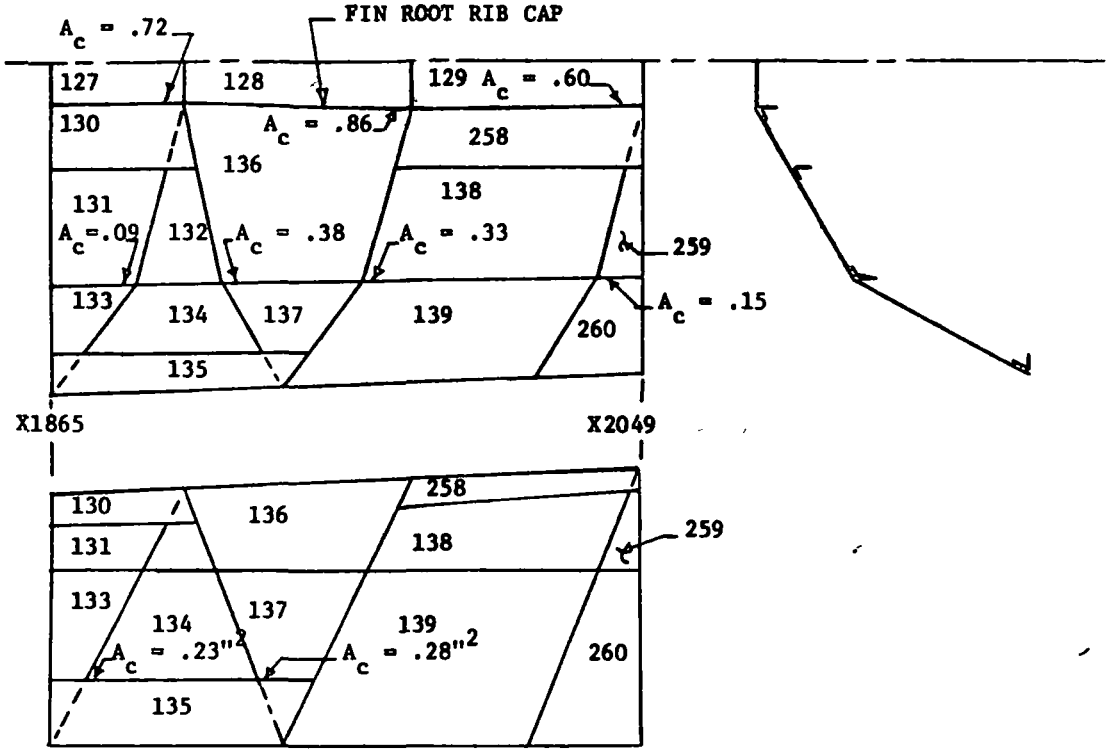
CAPS	~~190.5~~	148.3	
WEBS	160.9		
	~~351.4~~	308.7	
28%	~~TOL~~	86.4	
	~~458~~ LB	395.1	ITEM 58.2

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

SUMMARY OF PANEL THICKNESSES AND LONGERON AREAS
AFT FUSELAGE UPPER SHELL

NOTES:

1. MATERIAL: TITANIUM (Ti-6Al-6V-2Sn ALLOY)
2. A_c = CAP AREA IN SQUARE INCHES
3. $\bar{t}$ = EQUIVALENT THICKNESS, SKIN PLUS STIFFENER IN INCHES



PANEL	$\bar{t}$ AVG.(IN.)	PANEL	$\bar{t}$ AVG (IN.)
127	.055	135	.042
128	.058	136	.040
129	.037	137	.044
130	.034	138	.034
131	.034	139	.034
132	.037	258	.034
133	.045	259	.048
134	.040	260	.038

-	J GARRISON	BODY	AFT FUSELAGE UPR SKIN	Y

FIN ROOT RIB

CAPS

46 * .72 = 33.1 in^3
72 (.72+.80)½ = 68.5 in^3
78 (.80+.60)½ = 57.0 in^3
158.6 in^3 * .164 = 26 LB/SIDE

WEB

14 * 46 * .055 = 35.4 in^3
14 * 74 * .058 = 60.1 in^3
14 * 78 * .037 = 40.9 in^3
135.9 in^3 * .164 = 22 LB / SIDE

CAPS	52
WEB	44
28%	27
TOTAL =	123 LB

2/

Upper Longeron

29 * 09	=	2 2
19 (09 + 38) ½	=	4.5
43 (.38 + 33) ½	=	15 3
75 (.33)	=	24.8
20 (.33 + .15) ½	=	4 8

51.6 in³ * .164 * 128 = 11 LB/SIDE

Lwr Longeron

148 (.23 + .28) ½ = 37 7 in³ * .164 * 128 = 8 LB/SIDE

Upper Skin

79 * 198 * 040 * .164 * 1.28 = 131 LB/SIDE

Lwr Skin

63 * 203 * 045 * .164 * 128 = 121 LB/SIDE

Summary

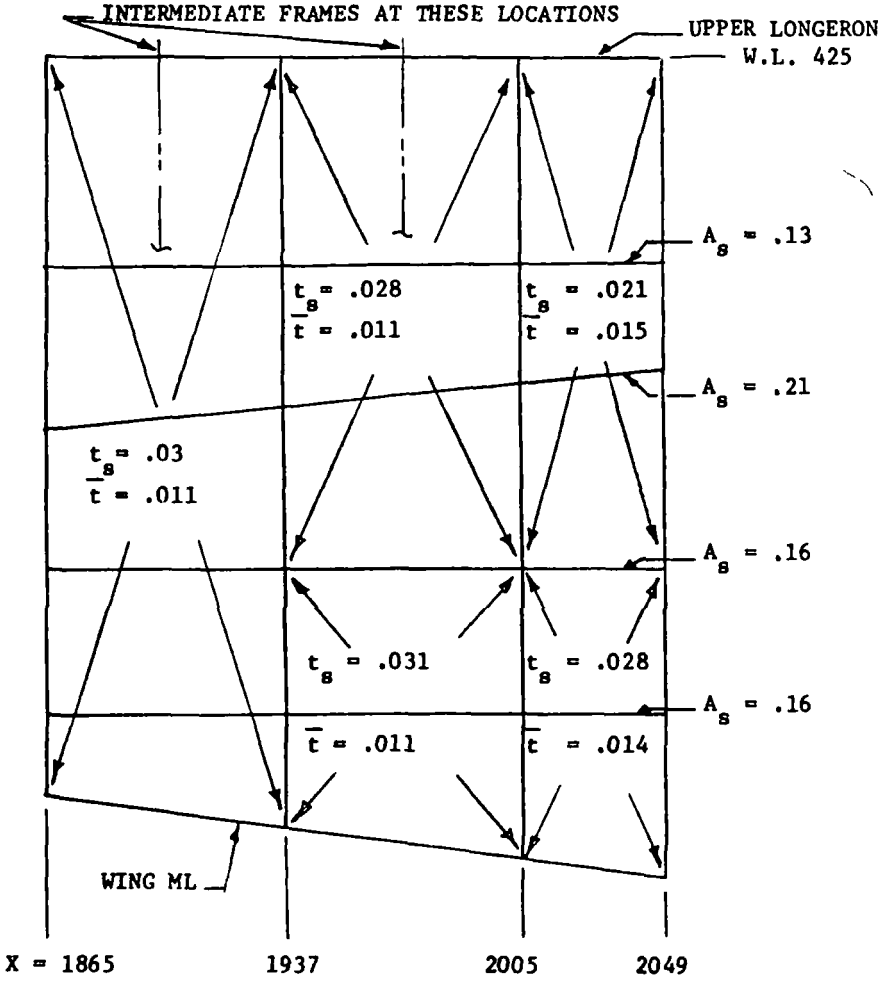
Skin & Stgr	504 LB
Upr Longeron	22 LB
Lwr Longeron	16 LB
Root Splice Rib	123 LB
Total	665 LB

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

AFT FUSELAGE SIDE PANEL

NOTES:

1. MATERIALS: WEBS, TITANIUM (Ti-6Al-6V-2Sn)
   WEB STIFFENERS, BORON-ALUMINUM
   STRINGERS, TITANIUM (Ti-6Al-6V-2Sn)
2. A_s = CAP AREA IN SQUARE INCHES
   t_s = SKIN THICKNESS IN INCHES
   $\bar{t}$ = WEB STIFFENER EQUIVALENT THICKNESS IN INCHES



	J GARRISON	BODY	AFT FUSELAGE INNER SKIN	Y

SKIN FS 1865 - 1937

$(247 + 253)\frac{1}{2} * 72 * .030 * .164 * 1.28$ = 118 LB/SIDE

STIFF FS 1865 - 1937

$(247 + 253)\frac{1}{2} * 72 * .011 * .095 * 1.28$ = 24 LB/SIDE

SKIN FS 1937 - 2005

$(253 + 263)\frac{1}{2} * 68 * .030 * .164 * 1.28$ = 111 LB/SIDE

STIFF FS 1937 - 2005

$(253 + 263)\frac{1}{2} * 68 * .011 * .095 * 1.28$ = 24 LB/SIDE

SKIN FS 2005 TO 2100

$264\ (65 + 94)\frac{1}{2} * .025 * .164 * 1.28$ = 110 LB/SIDE

STIFF FS 2005 TO 2100

$264\ (65 + 94)\frac{1}{2} * .015 * .095 * 1.28$ = 38 LB/SIDE

SUB TOTAL 420 LB/SIDE

2/

STRINGERS

211 * .13 * .164 * 1.28 = 6 LB/SIDE

220 * .21 * .164 * 1.28 = 10 LB/SIDE

224 * .16 * .164 * 1.28 = 8 LB/SIDE

230 * .16 * .164 * 1.28 = 8 LB/SIDE

32 LB/SIDE

LONGERON (WL 425)

210 * (.84 + .1) * .164 * 1.1 = 36 LB/SIDE

SUMMARY

SKIN & STIFF	840 LB
STRINGERS	64 LB
LONGERON	72 LB
TOTAL	976 LB
UPR	665
	1641 LB ITEM 55

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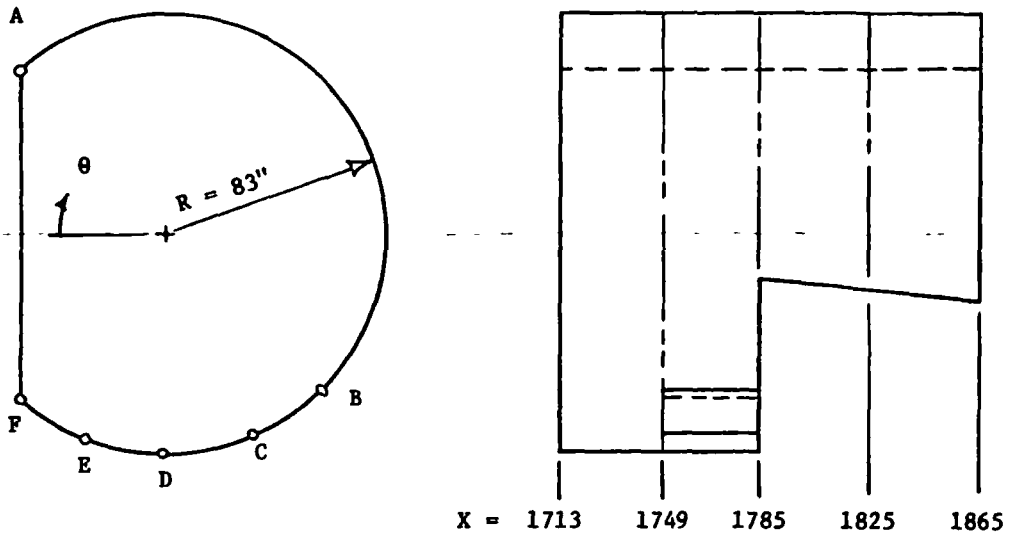
LH_2 TANK SKIRT EXTENSION

SUMMARY OF LONGERON AREAS AND SHELL THICKNESS

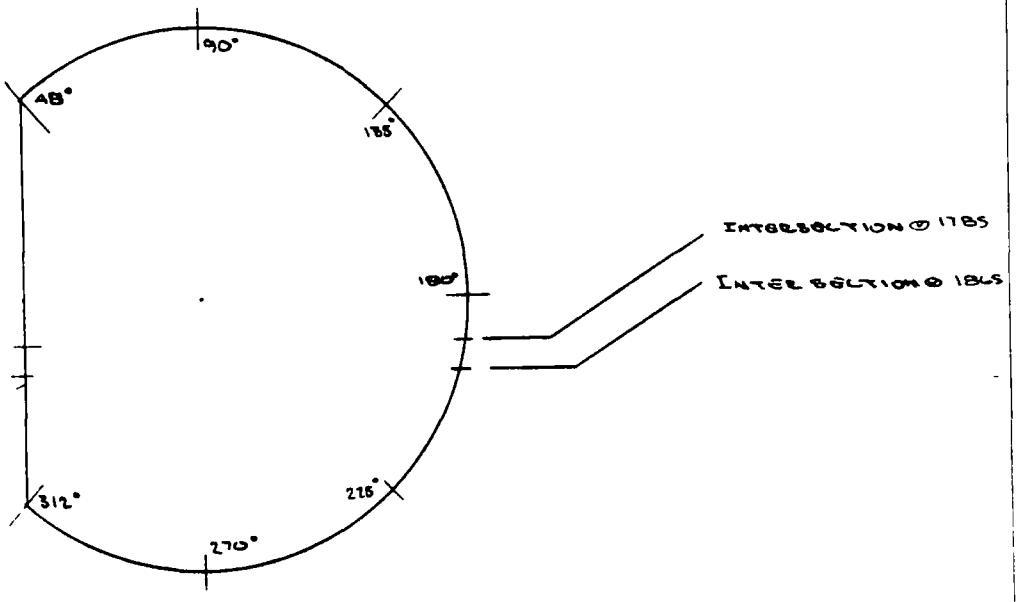
MATERIAL: TITANIUM (Ti-6Al-6V-2Sn ALLOY)



θ	SHELL THICKNESSES ($\bar{t}$), IN.				
	X = 1713	1749	1785	1825	1865
0	.047	.053	.053	.048	.046
48	.080	.077	.074	.069	.069
90	.061	.058	.053	.047	.044
135	.061	.054	.048	.044	.044
180	.050	.048	.049	.044	.044
225	.045	.045	.044	----	----
270	.047	.047	.044	----	----
312	.046	.045	.044	----	----
LONGERON AREAS - IN^2					
A	0	.53	.8	2.1	5.5
B	-	0	.20	---	---
C		0	.17		
D		0	.16		
E		0	.16		
F		0	.33		

J GARRISON	BODY	AFT TANK EXTENTION	1/

MATERIAL 6-6-2 Ti



CENTER WEB AREAS

FS 1713
$[.047 * 62 + 62(.097 + .080)\frac{1}{2}]$ = 6.85 IN^2

FS 1749
$[(.053 + .045)\frac{1}{2} * 62 + (.063 + .077)\frac{1}{2} * 62]$ = 7.07 IN^2

FS 1785 FWD
$(.083 + .044)\frac{1}{2} * 62 + (.053 + .074)\frac{1}{2} * 62$ = 6.94 IN^2

FS 1785 AFT
$.053 * 18 + (.063 + .074)\frac{1}{2} * 62$ = 4.68 IN^2

FS 1825
$.048 * 18 + (.048 + .069)\frac{1}{2} * 62$ = 4.49 IN^2

FS 1865
$.046 * 23 + (.046 + .069)\frac{1}{2} * 62$ = 4.62 IN^2

2/

SHELL AREAS / SIDE

FS 1713

$61(.080+.061)\frac{1}{2} + 65(.061+.061)\frac{1}{2} + 65(.061+.050)\frac{1}{2} + 65(.050+.045)\frac{1}{2}$
$+ 65(.045+.047)\frac{1}{2} + 61(.047+.044)\frac{1}{2}$ = 20.79 in^2

FS 1749

$61(.077+.058)\frac{1}{2} + 65(.058+.054)\frac{1}{2} + 65(.054+.048)\frac{1}{2} + 65(.048+.045)\frac{1}{2}$
$+ 65(.045+.047)\frac{1}{2} + 61(.047+.045)\frac{1}{2}$ = 19.89 in^2

FS 1785 FWD

$61(.074+.053)\frac{1}{2} + 65(.053+.048)\frac{1}{2} + 65(.048+.049)\frac{1}{2} + 65(.049+.044)\frac{1}{2}$
$+ 65*.044 + 61*.044$ = 18.88 in^2

FS 1785 AFT

$61(.074+.053)\frac{1}{2} + 65(.053+.048)\frac{1}{2} + 65(.048+.049)\frac{1}{2} + 19*.049$ = 10.99 in^2

FS 1825

$61\{.069+.047)\frac{1}{2} + 65(.047+.044)\frac{1}{2} + 65(.044) + 19*.044$ = 10.19 in^2

FS 1865

$61(.069+.044)\frac{1}{2} + 65*.044 + 65*.044 + 25*.044$ = 10.27 in^2

CENTER WEB WT

1713 - 1749

$(6.85+7.07)\frac{1}{2} * 36 * .164$ = 41 LB

1749 - 1785

$(7.07+6.94)\frac{1}{2} * 36 * .164$ = 41 LB

1785 - 1825

$(4.68+4.99)\frac{1}{2} * 40 * .164$ = 30 LB

1825 - 1865

$(4.99+4.62)\frac{1}{2} * 40 * .164$ = 30 LB

SUB TOTAL 142 LB

3/

SHELL WT

1713-1749
(20.79 + 19.89) ½ * 36 * .164 = 120 LB

1749-1785
(19.89 + 18.88) ½ * 36 * .164 = 114 LB

1785-1825
(10.99 + 10.19) ½ * 40 * .164 = 70 LB

1825-1865
(10.19 + 10.27) ½ * 40 * .164 = 67 LB

SUB TOTAL = 371 LB/SIDE

LONGERONS

A $[36*.53*\frac{1}{2} + 36(.53+.8)\frac{1}{2} + (.8+2.1)\frac{1}{2}*40 + (2.1+5.6\frac{1}{2})*40]\ .164$ = 40 LB

B $(36*2)\frac{1}{2} * .164$ = .6 LB/SIDE

C $36 * .17 * \frac{1}{2} * .164$ = .5 LB/SIDE

D $36 * .16 * \frac{1}{2} * .164$ = .5 LB/SIDE

E $36 * .16 * \frac{1}{2} * .164$ = .5 LB/SIDE

F $36 * .33 * \frac{1}{2} * .164$ = 1.0 LB

SUB TOTAL = 45 LB

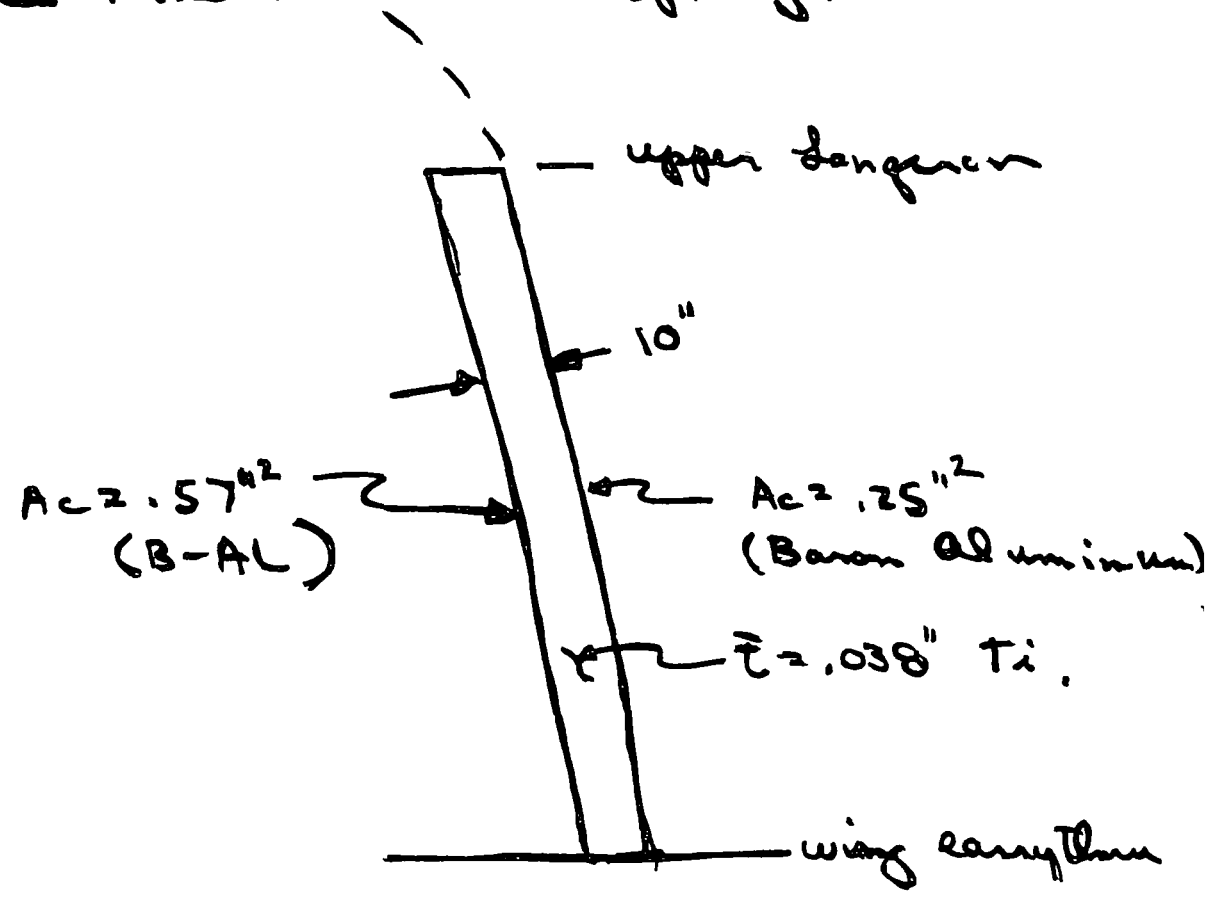
4/

AFT TANK EXTENTION

SUMMARY

CENTER WEB	142	
LH SHELL	371	
RH SHELL	371	
LONGERONS	45	
28% NON OPT	260	
TOTAL	1189 LB	ITEM 40

Intermediate Frames, Aft Fuselage Side Panel. ~ 36" Spacing.



INTERMEDIATE FRAMES

WEB
.038 * 10 * 265. * .164 * 1.28 = 20 LB/SIDE

INNER CAP
.67 * 255 * .095 * 1.28 = 18 LB/SIDE

OUTER CAP
.25 * 255 * 095 * 1.28 = 10 LB/SIDE

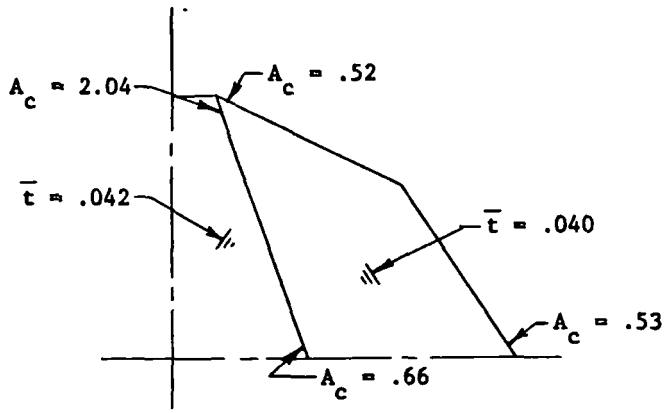
TOTAL 96 LB/FRAME

2 FRAMES REQ'D ITEMS 57.1
58.7

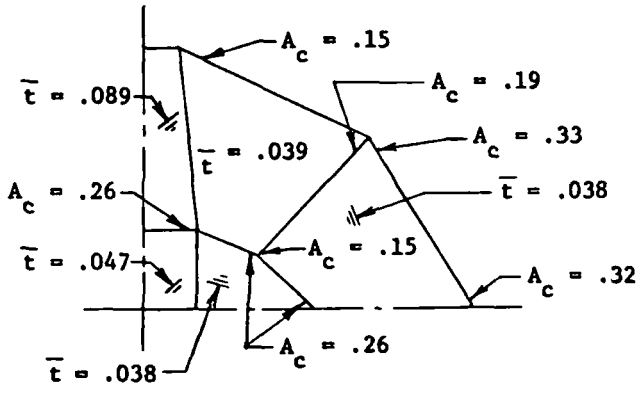
CANTED FRAMES AT X = 1865 & 1937
CAP AREAS AND PANEL THICKNESSES

NOTES:
1. MATERIAL: TITANIUM (Ti-6AL-6V-2Sn ALLOY)
2. AC = CAP AREAS IN SQUARE INCHES
   $\bar{t}$ = UNIT THICHNESS IN INCHES

FRAME CANTED AFT FROM X = 1865, Z = 425



FRAME CANTED FWD. FROM X = 1937, Z = 425



J GARRISON	BODY	AFT CANTED FRAMES	V

FS 1865 FRAME CANTED AFT α: 29°

MATERIAL 6-6-2 Ti

CAPS

ELE	L	A_1	A_2	WT/SIDE
1	13	.52	.52	11
2	60 * 1.14	52	.52	6.2
3	63 * 1.14	52	53	6.2
4	85 * 1.14	2.04	.66	21.5

SUB TOTAL 35.0 LB/SIDE

WEB

ELE	AREA	$\bar{t}$	WT/SIDE
1	2460	.042	16.9
2	4350	.040	28.5

SUB TOTAL 45.4 LB/SIDE

CAPS	70 LB
WEBS	91 LB
20%	45 LB
TOTAL	206 LB

ITEM 58.5

2/

FS 1937 FRAME CANTED FWD $\theta = 27°$

Caps

ELE	L	A_1	A_2	Wt/SIDE
1	13	.15	.15	3
2	63 *1.11	.15	.33	2.8
3	60 *1.11	.33	.32	3 6
4	50 *1.11	.19	.15	1.5
5	55 *1.11	.15	.15	1.5
6	16	.26	26	8
7	20	.26	.26	9
8	25	26	.26	1.2
9	25 *1.11	15	.15	.7

SUB TOTAL 13 3

Web

ELE	AREA	t	Wt/SIDE
1	850	089	12.4
2	2340	039	15 0
3	1960	038	12 2
4	500	038	3.1
5	440	047	3 4

SUB TOTAL 46 1 LB

Caps	27
Web	92
28%	33

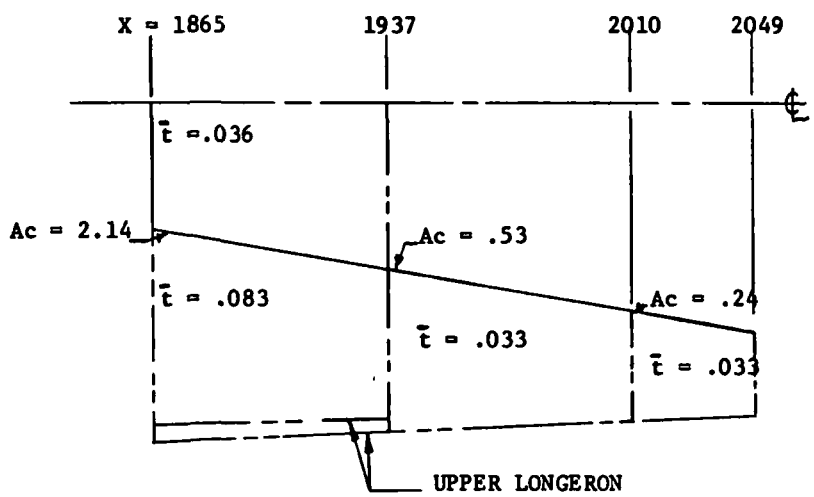
TOTAL 152 LB ITEM 58.6

DECK AT Z = 425

CAP AREAS AND PANEL THICKNESSES

NOTES:

1. MATERIAL: TITANIUM (Ti-6AL-6V-2Sn ALLOY)
2. Ac = AREA IN SQUARE INCHES
   $\bar{t}$ = UNIT THICKNESS IN INCHES



	J GARRISON	BODY	AFT DECK	Y

FS 1865 TO 2049

MATERIAL 6-6-2 Ti

CAPS

ELEMENT	L	A_1	A_2	WT/SIDE
1	74	2.14	.57	16.1
2	76	.53	.24	4.8
3	39	.24	.24	1.5

SUB TOTAL 22.4 LB/SIDE

WEBS

ELEMENT	AREA	t	WT/SIDE
1	4160	083	68.2
2	2960	033	16.0
3	1170	033	6 3

SUB TOTAL 90 5 LB/SIDE

CAPS	45 LB
WEBS	181 LB
28%	63
	289 LB

ITEM 55.6

J GARRISON	BODY	AFT SKIRT	Y

CONICAL SHELL

$C_1 = 125$ IN
$C_2 = 225$ IN
$L = 140$ IN

$A = (125+225)\frac{1}{2} * 140 = 24500$ IN^2

WT = $24500 * .038 * .164 * 1.28 = 175$ LB

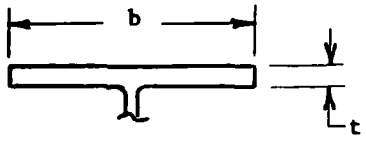
ITEM 55.5

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

THRUST STRUCTURE

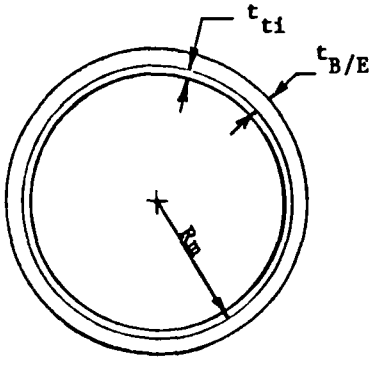
STRENGTH SIZING DATA FOR WEIGHT ANALYSIS

MACHINED COMPONENTS, MATERIAL TI-6AL-6V-2Sn ALLOY



MEMBER #	LENGTH IN.	b IN.	t IN.
441	103	9.0	.71
442	84.7	6.5	.42
443	24.7	2.5	.21
447	111.7	8.0	.48
448	96.7	7.5	.52
449	31.5	4.0	.32

TUBULAR MEMBERS, MATERIAL Ti-6AL-4V ALLOY WITH BORON-EPOXY OVERLAY



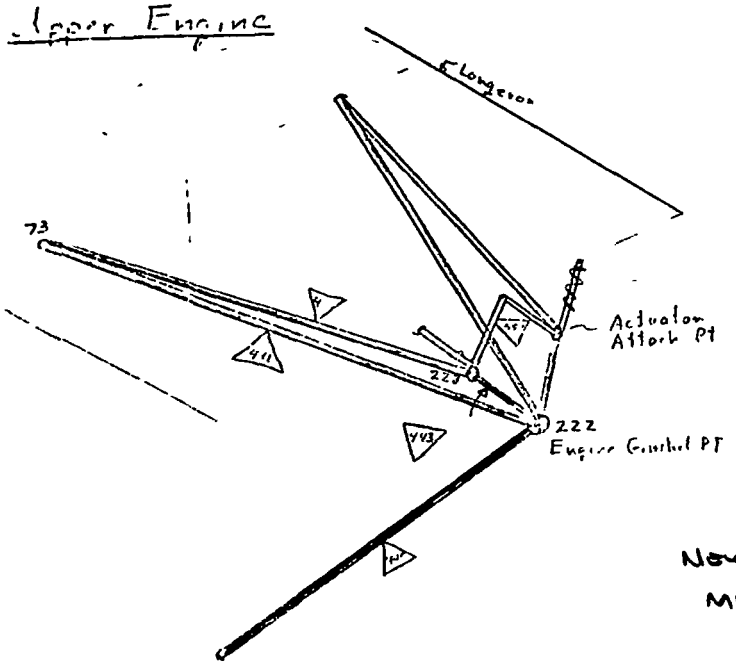
MEMBER #	LENGTH IN.	Rm IN.	t_{ti} IN.	$t_{B/E}$ IN.
444	25.7	.75	.040	.044
445	139.2	4.5	.040	.079
446	103.5	4.25	.040	.082
450	47.2	1.5	.040	.044

REFERENCE REPORT E0375, APPENDIX B-11 FOR MEMBER DESIGNATIONS

R. Lee
13 May '71

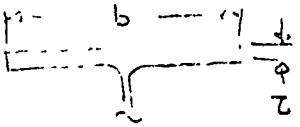
Thrust Structure, Data for weights analysis

Inner Engine



New Wt	1270
MP.10	1110
	+160 LB

Members 441, 442, 443, Machined Titanium Fitting (Ti-6-6-2 alloy)



Member	Length	b	τ
441	103"	9.0"	.71"
442	84.7"	6.5"	.42
443	24.7	2.5"	.21
Web.	$\bar{\tau}$ = .09"		

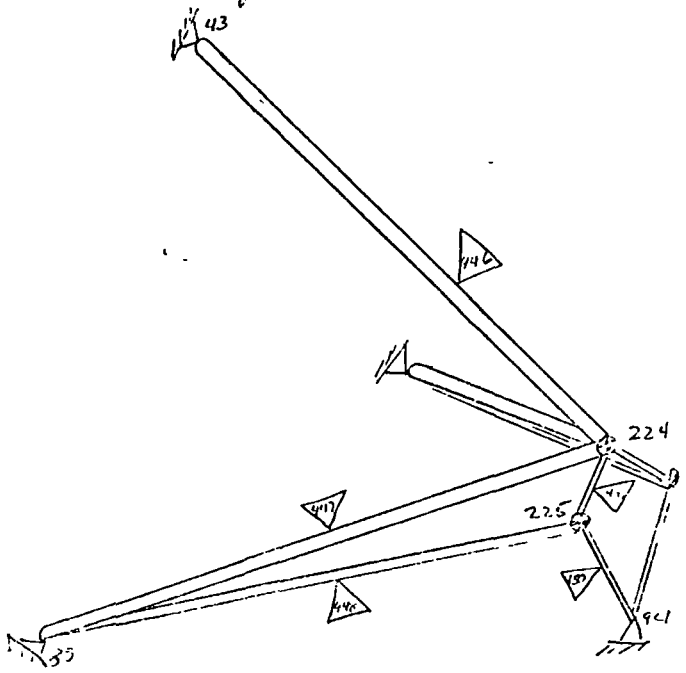
Members 444 & 445 6AL-4V tubes with Boron/Epoxy overlays.

Member	Length	r_{mean}	τ_{Ti}	$\tau_{B/E}$
444	25.7"	.75	.040	.044
445	139.2	4.50	.040	.079

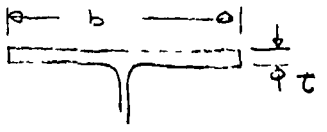
R. Lee
13 May '71

Thrust Structure, Data for weights analysis

Lower Engine



Members 447, 448 & 449, Machined Titanium Fitting (Ti-6-6-2 alloy)



Member	length	b	t
447	111.7"	8.0"	.48"
448	96.7	7.5	.52
449	31.5	4.0	.32
Web	$\bar{t}$ = .08 .09		

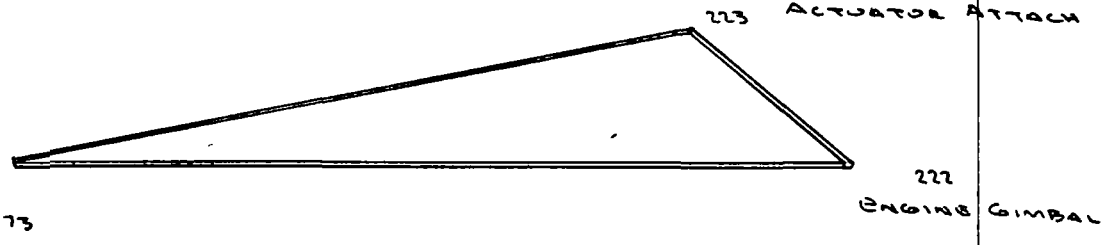
Members 446 and 450 6AL-4V Tubes with Boron-Epoxy overlay.

Member	length	R_{mean}	t_{Ti}	$t_{B/E}$
446	103.5	4.25"	.040	.082
450	47.2	1.5"	.040	.044

	J GARRISON	FUSELAGE	THRUST STRUCTURE	1/7

UPPER ENGINE SUPPORT

MACHINED TITANIUM FTG 2 REQ'D



WEB	103 × 16 × ¼ × 090	= 82.3 IN³
CAP 73-223	85 × 6.5 × .42 = 232	IN³
CAP 73-222	103 × 9 × .71 = 608	IN³
CAP 222-223	25 × 2.5 × .21 = 13	IN³
		935.3 IN³

BASIC WT 935.3 × 1.28 × .164 = 192 LB

ATTACH FTG AT P= 73 19 LB

211 LB

2/7

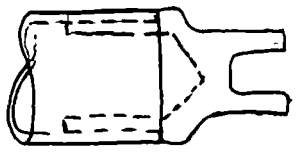
SINGLE STRUT

T1 $139 * 2*.45 * \pi * .040 = 157.5\ in^3$

B/E $139 * 2*4.5 * \pi * .079 = 311\ in^3$

WT = $157.5 * .164 = 26$
$311 * .075 = 24$
50 LB

END FTG



$9^2 \pi/4 * .8 = 31$

$9^2 \pi/4 \times .25 = 15$

$9\pi * 8 \times .25 = 50$

$95\ in^3 * .164 = 16$ LB / END

TOTAL = $82 * 1.28 = 105$ LB

3/7

ENGINE MOUNT

50 * 50 * .1 = 250 IN^3

WT = 250 * .164 = 41 LB

GIMBAL BRG

$\pi \frac{4}{3} * 3^3 = 71\ IN^3$

$6^2 \pi * .75 = 85\ IN^3$

$156\ IN^3 * .283 = 45$ LB

96 LB

BIPOD

26 * .75 * 2π * .040 = 4.9 * .16 = .8

26 * .75 * 2π * .044 = 5.5 * .075 = 4

1.2 LB

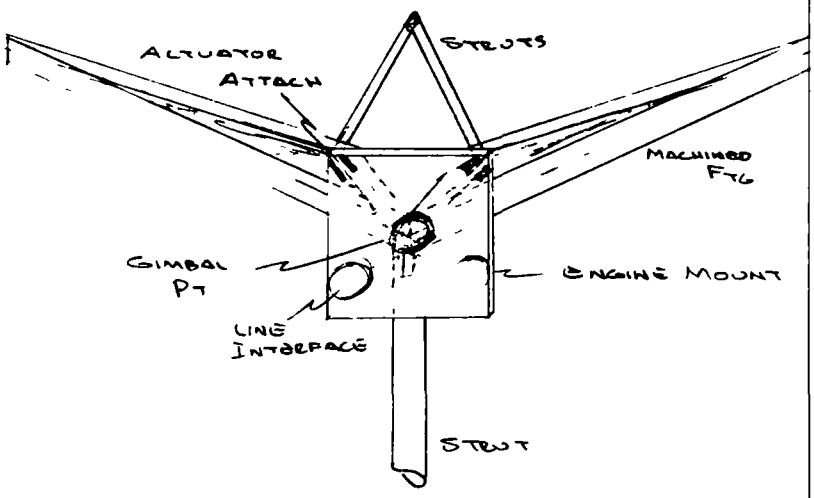
1.2 * 128 — 1.5 LB

FTG .5 LB

2.0 LB EACH

4/7

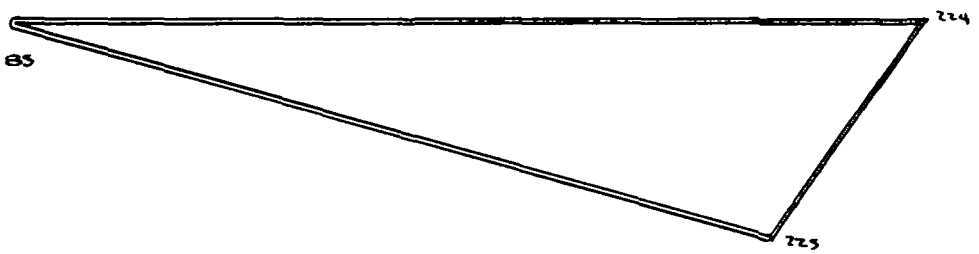
Upper Thrust Structure



Machined	Ftg	RH	211 lb
"	"	LH	211 lb
Engine	Mount		96 lb
Strut	Single		105 lb
Strut	Bipod		4 lb
		Total	627 lb

5/7

LOWER ENGINE SUPPORT



WEB	112 * 27 * ½ * .090	=	136 IN³
CAP BS-224	112 * 8 * .48	=	430 IN³
CAP BS-225	97 * 7.5 * .52	=	378 IN³
CAP 224-225	32 * 4 * 32	=	41 IN³
			985 IN³

BASIC WT = 985 * 1.28 * .164 = 206 LB

ATTACH FT. @ PT BS 21 LB

227 LB

6/7

STRUT

104 * 4.25 * 2π * .040 = 112 * .160 = 18
104 * 4.25 * 2π * .082 = 228 * .075 = 17

35 LB

END FTG $\left(\frac{4.25}{4.5}\right)^2 * 16 =$ 14 LB / END

TOTAL = 63 * 1.28 = 81 LB

BIPOD

47 * 1.5 * 2π * .040 = 18 IN^3 * .16 = 2.9
47 * 1.5 * 2π * .044 = 20 IN^3 * .075 = 1.5

44
FTG 1.6
60 LB

7/7

LOWER THRUST STRUCTURE

MACHINED FTG RH		227	
" " LH		227	
ENGINE MOUNT		96 LB	
SINGLE STRUT		81 LB	
BIPOD		12 LB	
		643 LB	
	CDR	627	
		1270 LB	Item 61

.-71	J GARRISON	BODY	NOSE GEAR PROJ

REF- MAC 747

$\gamma = .38(q)^{.3}(S_{Nd}) + .039(F_N L_a)^{.9}$

q = MAX DYNAMIC PRESSURE - PSF

S_{Nd} = DOOR AREA - FT^2

F_N = NOSE GEAR LOAD - KIPS

L_a = STRUT LENGTH (EXTENDED) - IN

DOOR STRUCTURE & MECHANISM IS A FUNCTION OF DOOR AREA

REACTION MATERIAL IS A FUNCTION OF STRUT LENGTH & LOAD

$\gamma = .38(700)^{.3}(42.2) + .039(106.7 * 185.5)^{.9}$

$= 114 + 216$

$= 330$ LB ITEM 81

13-71	J Garrison	Crew Cab	OSO-F	

Wt Summary

Crew Cab		Item
Pressure Barrier Increment	548	69
1 ~~2~~ O/H Hatches	45 ~~90~~	70.5
1 Aft Hatch	59	70.5
Window Framing	154 ~~355~~	68
Windows	231 ~~[illegible]~~	68
Total	~~[illegible]~~	

Airlock		
Pressure Barrier Increment	625	70
1 O/H Hatch	77	70.5
1 Aft Hatch	60	70.5
Flex Tunnel Cabriso in Docking	~~[illegible]~~	
	~~[illegible]~~	

Total [illegible] LB

3-71	) GARRISON	CREW CAB	OSO-F	

CREW CAB

SECTION	GG	STA 880	AREA 2488 IN^2 CIRC	192 IN
	FF	929	5360 IN^2	312 IN
	AA	949	5696 IN^2	296 IN
	DD	1009	7664 IN^2 +40BU	350 IN
	WW	1076	12332	

CREW CAB PROPER 880 TO 1009

880 - 929 L = 49

$$V = \frac{2488}{5360}{}^{7848} * \frac{49}{2} * \frac{1}{1728} = 106 \ FT^3$$

929 - 949 L = 20

$$V = \frac{5360}{5696}{}^{11056} * \frac{20}{2} * \frac{1}{1728} = 65 \ FT^3$$

949 - 1009 L = 60

$$V = \frac{5696}{7664}{}^{13360} * \frac{60}{2} * \frac{1}{1728} = \frac{233}{404} \ FT^3$$

AIRLOCK SECTION & PRESS BAY 1009 - 1076

$$V = 12332 * \frac{67}{1728} = 478 \ FT^3$$

$$\gamma = 1.54 (V_c)^{.78} (1 + P_c)^{.35}$$

V_c = VOLUME

P_c = CLT DIFF PRESS = 14.7 * 2 = 29.4

	TYPE	SIZE	AREA	WT	ρ	MOM WT	ρ
ΔP	AIRLOCK	48"D	1810	30	.0276	30	
	C-S BSC.	22x36	792	35	.0442	3	
ΔP	"	24x40	960	30	.0312	3	
ΔP	"	22" D	380	11.4	.0300	7.2	
	"	36x36	1296	40	.0309	4.2	
	C-S BNT.	40x71		52			
		36x72					
ΔP		30x60	1800	56	.0310		
					AREA	WT@ .033	
2	O/H HATCH	@ 25x54			1350	45	
	AIRLOCK HATCH		40 x 58		2320	77	
	AFT CAB HATCH		30 x 60		1800	59	
	AFT AIRLOCK HATCH		48 IN D		1810	60	

$\gamma = (878)^{.78} * 1.54 * (30.4)^{.35}$

$= 198 * 1.54 * 33$

$= 198 * 5.08$

$= 1005$ # Total Comparison Only

$\gamma = 5.08\,(404)^{.78} + 5.08\,(478)^{.79}$

$= 5.08 * 108 + 5.08 * 123$

$= 548 + 625$

$= 1173$ # Total Use

Windows & Framing DC-10 & SLV 4-24-70

Window Area	5100 in²	35
Cut Out Area	6440 in²	
Frames	355	= 10 psf
Window	538	= 15 psf
Total	893 #	

$\rho = \frac{893}{35.3} = 25$ psf

Shuttle 2219 in² = 154 ft²

Frame	154
Window	231
	385

HATCH AIRLOCK 48 IN DIAM

MACHINED PART	27
10" D WINDOW FRAME	4
" " " GLASS	3
DEBRIS GUARD	8
HINGE FTG	3
STIFFENERS	3
SUB TOTAL	50
MECHANISM	30
TOTAL	80#

EQUIPMENT COMPARTMENTS

ASSUME 01.5 BASIC GAGE
ADD 25% FOR STIFFENING
ADD 25% FOR FRAMING

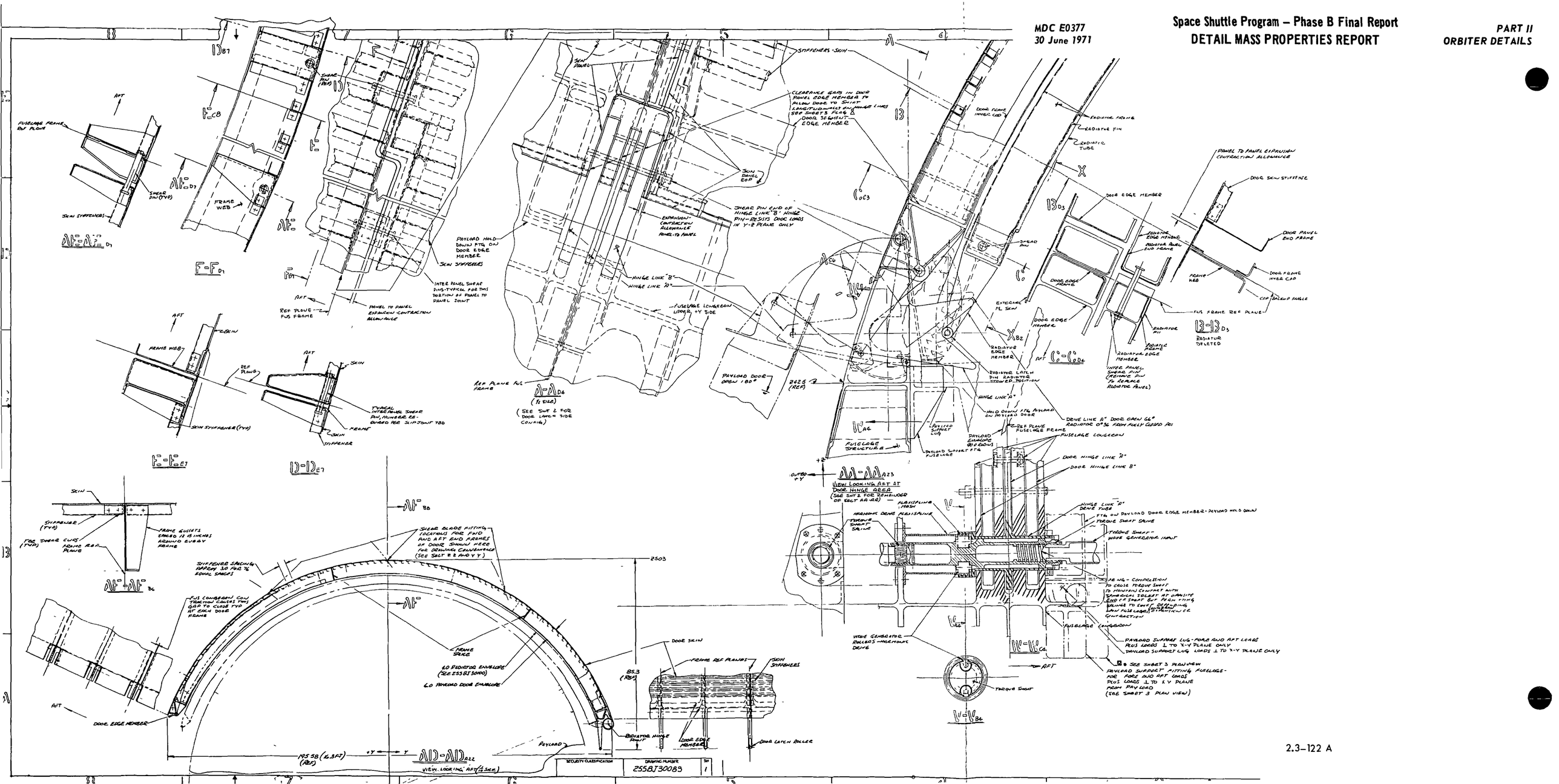
ρ = 015 * 1.5 * 144 * .160 = .52 PSF

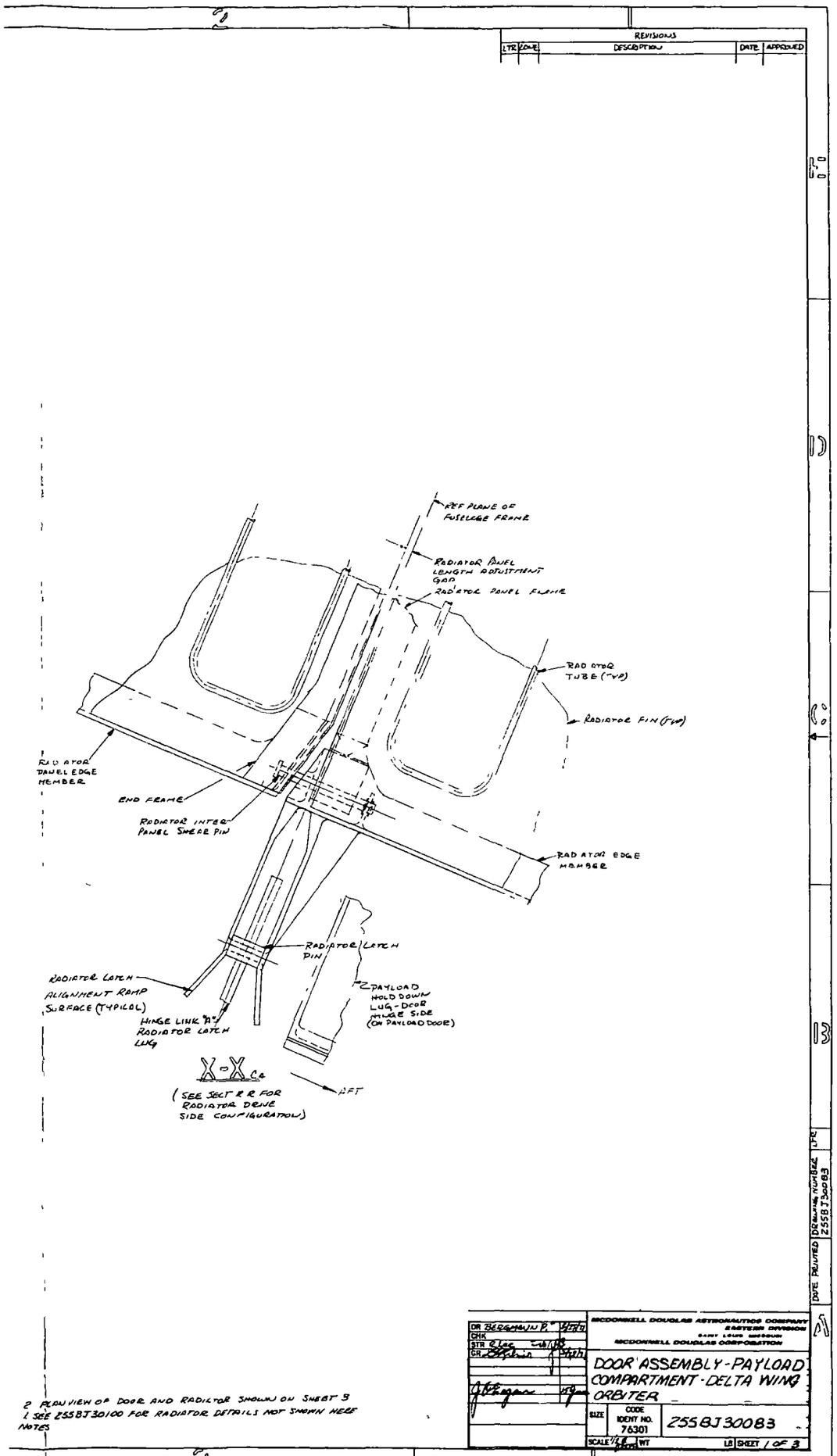
FWD CPT 466 FT^2 / SIDE
AFT CPT 54 FT^2 / SIDE

TOTAL = 520 * 2 = 1040 FT^2

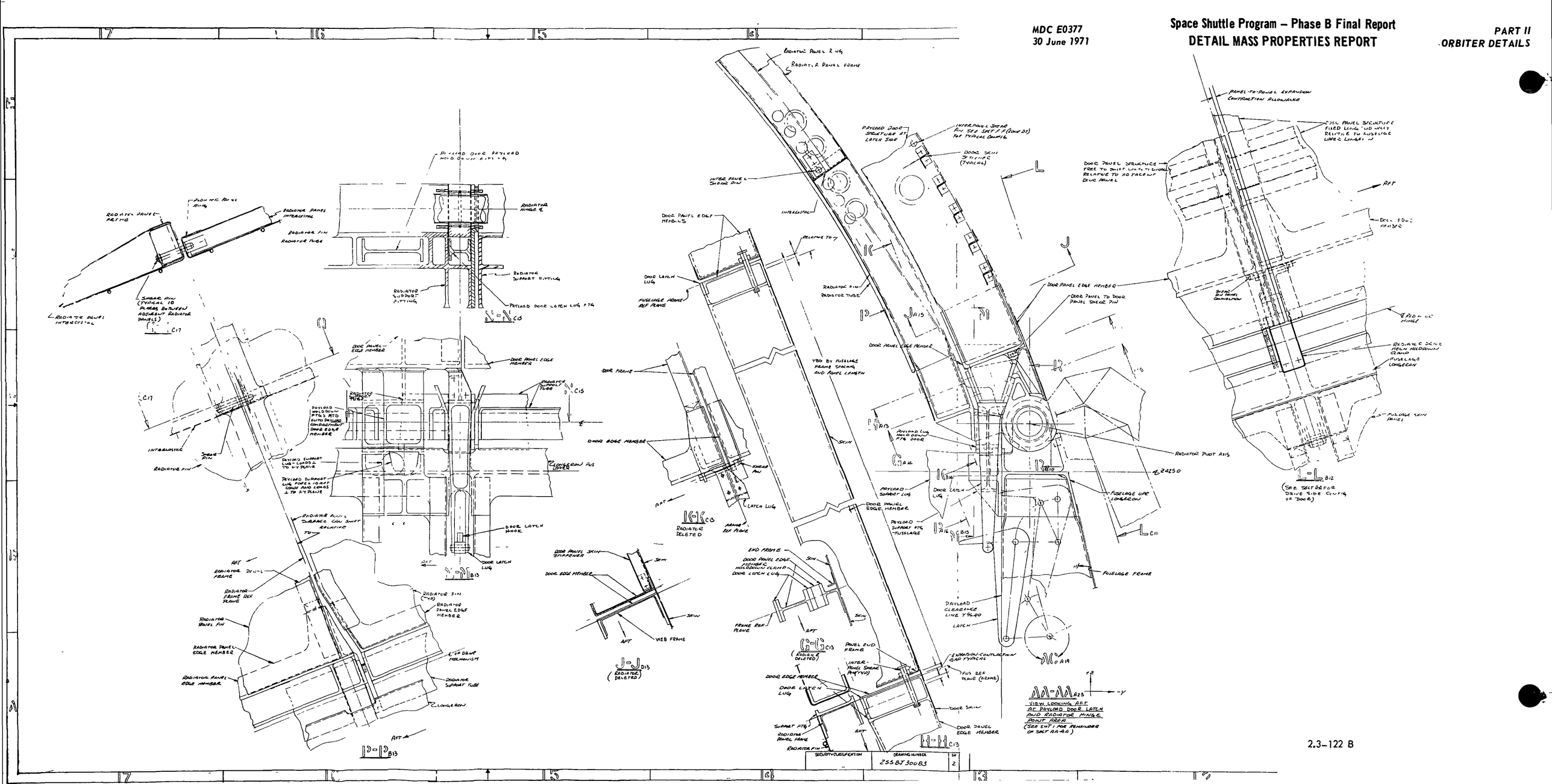
WT = 1040 * .52 * 1.17 (NON OPT) = 631 LB

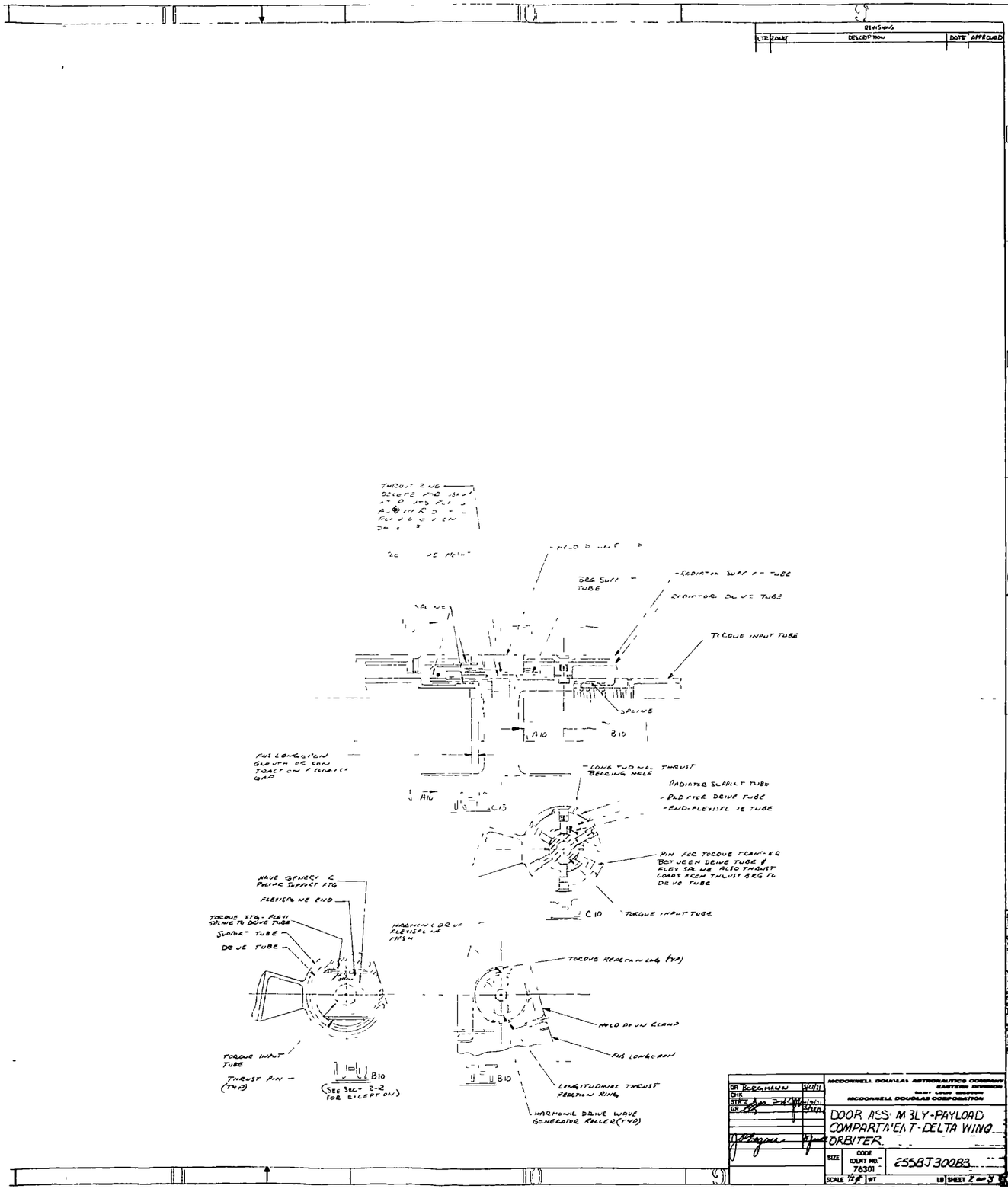
507 LB FWD ITEM 72
124 LB AFT 73


FUSELAGE FRAME REF PLANE
SHEAR PIN (TYP)
SKIN STIFFENERS
FRAME WEB
SHEAR PIN (REF)
SKIN PANEL
STIFFENERS - SKIN
CLEARANCE GAPS IN DOOR PANEL EDGE MEMBER TO ALLOW DOOR TO SHUT (LENGTH DIMENSIONS ON HINGE LINES SEE SHEET 3 PLAN VIEW)
DOOR SHUT-EDGE MEMBER
SKIN PANEL EDGE
EXPANSION-CONTRACTION ALLOWANCE PANEL-TO PANEL
SHEAR PIN END OF HINGE LINE "B" HINGE PIN-RESTS DOOR LOADS IN Y-Z PLANE ONLY
PAYLOAD HOLD DOWN FTG ON DOOR EDGE MEMBER
SKIN STIFFENERS
INTER PANEL SHEAR PINS-TYPICAL FOR THIS LOCATION OF PANEL TO PANEL JOINT
PANEL TO PANEL EXPANSION CONTRACTION ALLOWANCE
REF PLANE FUS FRAME
HINGE LINE "B"
HINGE LINE "A"
FUSELAGE LONGERON UPPER HY SIDE
PAYLOAD DOOR OPEN 180°
REF PLANE FUS FRAME
(½ SIDE)
(SEE SHT 2 FOR DOOR LATCH SIDE CONFIG)
FRAME WEB
SKIN STIFFENER (TYP)
TYPICAL INTEGRAL SHEAR PIN, NUMBER REQUIRED PER SLIP JOINT TBD
SKIN STIFFENER
FRAME
DOOR LATCH INNER CAP
RADIATOR FRAME
RADIATOR FIN
RADIATIC TUBE
PANEL TO PANEL EXPANSION CONTRACTION ALLOWANCE
DOOR SKIN STIFFENR
DOOR EDGE MEMBER
RADIATOR PANEL END FRAME
DOOR PANEL END FRAME
DOOR EDGE MEMBER
SHEAR PIN
DOOR EDGE MEMBER
RADIATOR EDGE MEMBER
RADIATOR PIN
RADIATOR EDGE MEMBER
INTER PANEL SHEAR PIN (REMOVE PIN TO REMOVE RADIATOR PANEL)
DOOR FRAME INNER CAP
DOOR SKIN
FUS FRAME REF PLANE
RADIATOR DELETED
RADIATOR LATCH PIN RADIATOR STOWED POSITION
HOLD DOWN FTG PAYLOAD ON PAYLOAD DOOR
DRIVE LINK "A" DOOR OPEN 66° RADIATOR 0°% FROM FULLY CLOSED POS
REF PLANE FUSELAGE FRAME
FUSELAGE LONGERON
DOOR HINGE LINK "A"
DOOR HINGE LINK "B"
HINGE LINK "A" DENE TUBE
FTG ON PAYLOAD DOOR EDGE MEMBER - PAYLOAD HOLD DOWN
TORQUE SHAFT SKIN
TORQUE SHAFT - WAVE GENERATOR INPUT
PAYLOAD SUPPORT FTG FUSELAGE
FUSELAGE STRUCTURE
PAYLOAD SUPPORT LUG
PAYLOAD LONGERON
PAYLOAD SUPPORT FTG FUSELAGE
OUTBD +Y
VIEW LOOKING AFT AT DOOR HINGE AREA
(SEE SHT 2 FOR DEFINITION OF SECT AA-AA)
PLASTIFILM TAPE
HARMONIC DRIVE ASSEMBLY
TORQUE SHAFT SKIN
WAVE GENERATOR BULLETS - HARMONIC DRIVE
TORQUE SHAFT
FUSELAGE
PAYLOAD SUPPORT LUG - FORE AND AFT LOADS PLUS LOADS ⊥ TO X-Y PLANE ONLY
PAYLOAD SUPPORT LUG LOADS ⊥ TO X-Y PLANE ONLY
SEE SHEET 3 PLAN VIEW
PAYLOAD SUPPORT FITTING FUSELAGE - FOR FORE AND AFT LOADS PLUS LOADS ⊥ TO X-Y PLANE FROM PAYLOAD (SEE SHEET 3 PLAN VIEW)
AFT
TORQUE SHAFT
SKIN
STIFFENER (TYP)
FRAME GUSSETS SPACED 12.5 INCHES AROUND OVARY FRAME
FOR SHEAR CLIPS (TYP)
FRAME REF PLANE
STIFFENER SPACING VARIES 30 FOR ½ EQUAL SPACES
FUS LONGERON CONTRACTION CAUSES THIS GAP TO CLOSE TYP AT EACH DOOR FRAME
SHEAR BLADE FITTING INCREASES PAD FLUID AND AFT END FRAMES OF DOOR SHOWN HERE FOR DRAWING CLARITY (SEE SHT 8 & VV)
2503
FRAME SPACE
60 RADIATOR ENVELOPE (SEE 255BT30090)
60 PAYLOAD DOOR ENVELOPE
DOOR SKIN
FRAME REF PLANES
SKIN STIFFENERS
BS 3 (REF)
RADIATOR HINGE POINT
DOOR EDGE MEMBER
DOOR LATCH ROLLER
AFT
DOOR EDGE MEMBER
PAYLOAD
1853.8 (6.3 FT) (REF)
VIEW LOOKING AFT (½ SHOWN)
SECURITY CLASSIFICATION
DRAWING NUMBER
255BT30089
SH 1

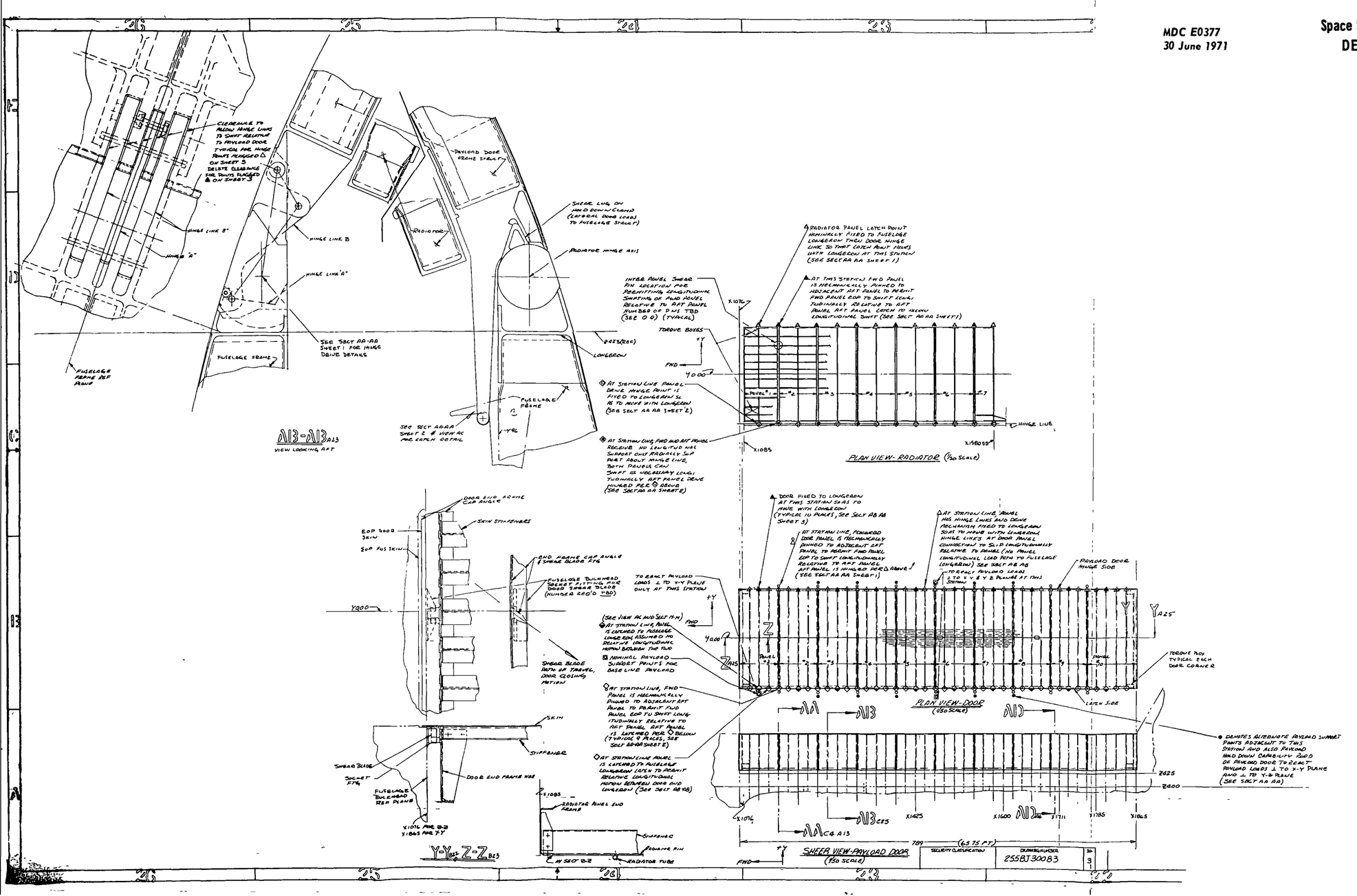

REVISIONS
LTR ZONE DESCRIPTION DATE APPROVED
REF PLANE OF FUSELAGE FRAME
RADIATOR PANEL LENGTH ADJUSTMENT GAP
RADIATOR PANEL FLEXIE
RAD OTBD TUBE (TYP)
RADIATOR FIN (TYP)
RADIATOR PANEL EDGE MEMBER
END FRAME
RADIATOR INTER-PANEL SHEAR PIN
RADIATOR EDGE MEMBER
RADIATOR LATCH PIN
PAYLOAD HOLD DOWN LUG - DOOR HINGE SIDE (ON PAYLOAD DOOR)
RADIATOR LATCH ALIGNMENT RAMP SURFACE (TYPICAL)
HINGE LINK "A" RADIATOR LATCH LUG
X-X
(SEE SECT B-B FOR RADIATOR DRIVE SIDE CONFIGURATION)
AFT
NOTES
2 PLAN VIEW OF DOOR AND RADIATOR SHOWN ON SHEET 3
1 SEE 2558J30100 FOR RADIATOR DETAILS NOT SHOWN HERE
DR BERGMANN P.
CHK
STR ELEC
DR
MCDONNELL DOUGLAS ASTRONAUTICS COMPANY EASTERN DIVISION
MCDONNELL DOUGLAS CORPORATION
DOOR ASSEMBLY-PAYLOAD COMPARTMENT-DELTA WING ORBITER
SIZE CODE IDENT NO. 76301
2558J30083
SCALE WT LB SHEET 1 OF 3
DATE RELEASED DRAWING NUMBER LTR
2558J30083

2.3–122 A Continued

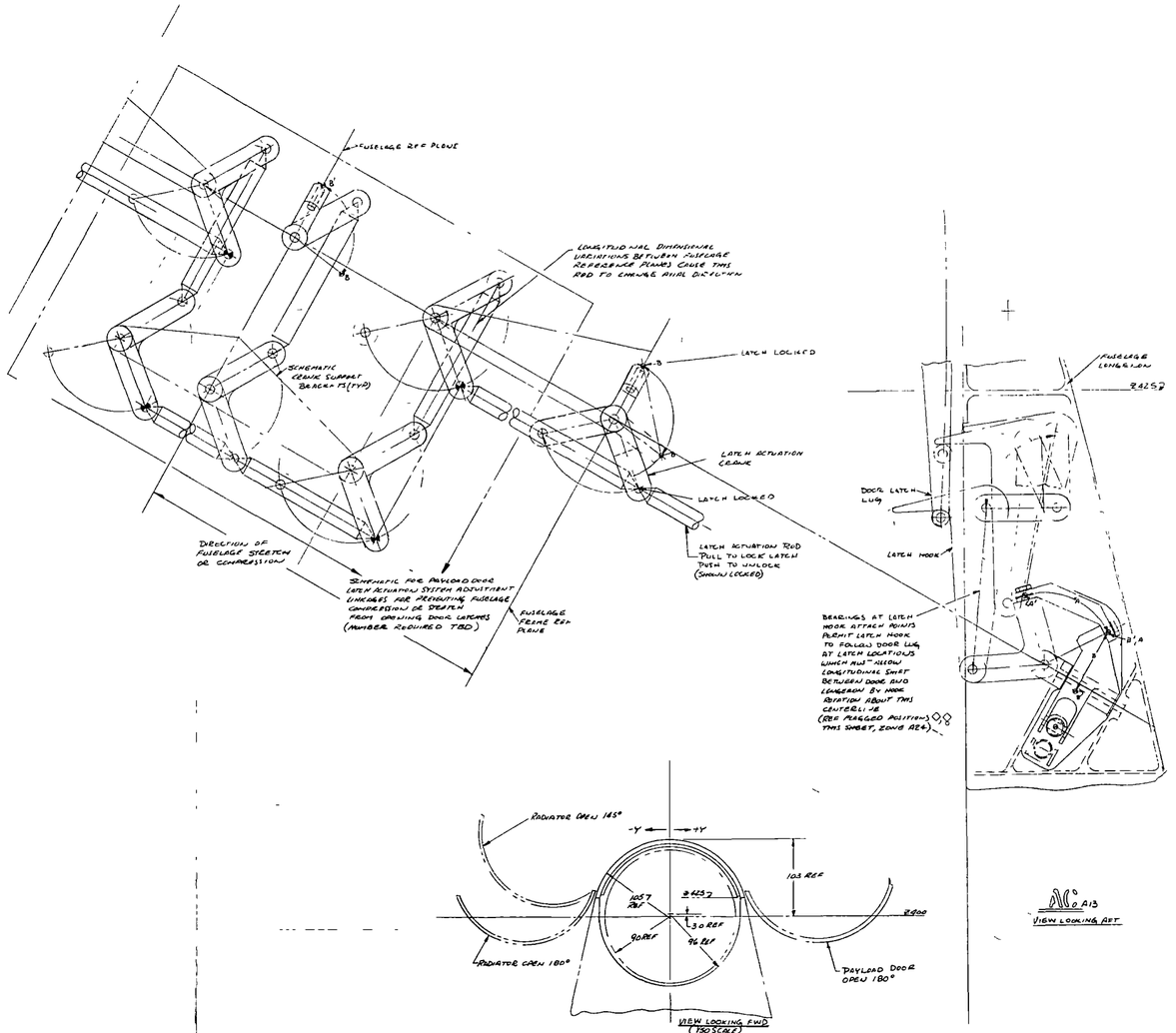

RADIATOR PANEL REFLTE
RADIATOR PANEL INTERCOSTAL
RADIATOR PANEL RING
SHEAR PIN (TYPICAL 10 PLACES BETWEEN ADJACENT RADIATOR PANELS)
PAYLOAD DOOR PAYLOAD HOLD DOWN FITTING
RADIATOR HINGE
RADIATOR FIN
RADIATOR TUBE
RADIATOR SUPPORT FITTING
PAYLOAD DOOR LATCH LUG FTG
DOOR PANEL EDGE MEMBER
RADIATOR TUBE
PAYLOAD HOLD DOWN FTGS ATD ENTD PAYLOAD COMPARTMENT SIDE BOW MEMBER
PAYLOAD SUPPORT LUG - LOADS ⊥ TO SKY PLANE
PAYLOAD SUPPORT LUG, FORE & OAFT LOADS AND LOADS ⊥ TO SKY PLANE
FUSELAGE FUS
RADIATOR PANEL CLEARANCE CAN SHIFT RELATIVE TO
DOOR LATCH HOOK
DOOR LATCH LUG
AFT
RADIATOR FRAME
RADIATOR FRAME REF PLANE
RADIATOR PANEL FIN
RADIATOR PANEL EDGE MEMBER
RADIATOR FIN (TYP)
RADIATOR PANEL EDGE MEMBER
LATCH MECHANISM
RADIATOR SUPPORT TUBE
LONGERON
RADIATOR PANEL EDGE MEMBER
RADIATOR PANEL RUG
RADIATOR PANEL STRUCTURE
INTER PANEL SHEAR PIN
DOOR PANEL EDGE MEMBERS
DOOR LATCH LUG
FUSELAGE FRAME REF PLANE
RELATIVE TO
RADIATOR PIN
RADIATOR TUBE
DOOR FRAME
DOOR EDGE MEMBER
SHEAR PIN
LATCH LUG
AFT
RADIATOR DELETED
ARMS REF PLANE
DOOR PANEL SKIN STIFFENER
SKIN
DOOR EDGE MEMBER
WEB FRAME
AFT
(RADIATOR DELETED)
TBD BY FUSELAGE FRAME SPACING AND PANEL LENGTH
SKIN
END FRAME
DOOR PANEL EDGE MEMBER & HOLDDOWN CLAMP
DOOR LATCH LUG
SKIN
FRAME REF PLANE
AFT
(RADIATOR DELETED)
PANEL END FRAME
INTER-PANEL SHEAR PIN (TYP)
DOOR EDGE MEMBER
DOOR LATCH LUG
SUPPORT FTG
RADIATOR PANEL FRAME
RADIATOR FIN
AFT
PAYLOAD DOOR STRUCTURE AT LATCH SIDE
INTER PANEL SHEAR PIN SEE SHT 7 A (ZONE D1) FOR TYPICAL CHAMFER
DOOR SKIN STIFFIC (TYPICAL)
DOOR PANEL STRUCTURE FREE TO SHIFT LONG'L & LAT'L RELATIVE TO ADJACENT DOOR PANEL
DOOR PANEL EDGE MEMBER
DOOR PANEL TO DOOR PANEL SHEAR PIN
DOOR PANEL EDGE MEMBER
PAYLOAD LUG HOLD DOWN FTG DOOR
RADIATOR PIVOT AXIS
PAYLOAD SUPPORT LUG
DOOR LATCH LUG
PAYLOAD SUPPORT FTG - FUSELAGE
DOOR PANEL EDGE MEMBER
FUSELAGE UPR LONGERON
FUSELAGE FRAME
PAYLOAD CLEARANCE LINE Y 540
LATCH
EXPANSION-CONTRACTION GAP TYPICAL
FUS REF PLANE (FRAME)
DOOR SKIN
DOOR PANEL EDGE MEMBER
VIEW LOOKING AFT AT PAYLOAD DOOR LATCH AND RADIATOR HINGE POINT AREA
(SEE SHT 1 FOR REMAINDER OF SECT AA-AA)
PANEL-TO-PANEL EXPANSION CONTRACTION ALLOWANCE
STEEL PANEL STRUCTURE FIXED LONG'L & LAT'L RELATIVE TO FUSELAGE UPPER LONGERON
AFT
DOOR EDGE MEMBER
SHEAR PIN PANEL CONNECTION
RADIATOR HINGE
RADIATOR DRIVE MECH HOLDDOWN CLAMP
FUSELAGE LONGERON
FUSELAGE SKIN PANEL
(SEE SECT AA FOR DRIVE SIDE CONFIG OR DOOR)
SECURITY CLASSIFICATION
DRAWING NUMBER
SH
2SSBJ30083
2



2.3–122 B Continued


CLEARANCE TO ALLOW HINGE LINKS TO SWEEP RELATIVE TO PAYLOAD DOOR TYPICAL FOR HINGE POINTS FLAGGED △ ON SHEET 3 DELETE CLEARANCE FOR POINTS FLAGGED ▲ ON SHEET 3
HINGE LINE B
HINGE LINE 'A'
PAYLOAD DOOR FRAME STRUT
RADIATOR
RADIATOR HINGE AXIS
SHEAR LUG ON HOLD DOWN CLEVIS (LATERAL DOOR LOADS TO FUSELAGE STRUT)
SEE SECT AA-AA SHEET 1 FOR HINGE DRIVE DETAILS
FUSELAGE FRAME
FUSELAGE FRAME REF PLANE
Δ13-Δ13A13
VIEW LOOKING AFT
SEE SECT AAAA SHEET 2 & VIEW MC FOR LATCH DETAIL
FUSELAGE FRAME
Y=L
INTER PANEL SHEAR PIN LOCATION FOR PERMITTING LONGITUDINAL SHIFTING OF FWD PANEL RELATIVE TO AFT PANEL NUMBER OF PINS TBD (SEE D D) (TYPICAL)
RADIATOR PANEL LATCH POINT NORMALLY FIXED TO FUSELAGE LONGERON THRU DOOR HINGE LINE SO THAT LATCH POINT MOVES WITH LONGERON AT THIS STATION (SEE SECT AA AA SHEET 1)
AT THIS STATION FWD PANEL IS MECHANICALLY PINNED TO ADJACENT AFT PANEL TO PERMIT FWD PANEL EDP TO SHIFT LONGITUDINALLY RELATIVE TO AFT PANEL AFT PANEL LATCH TO ALLOW LONGITUDINAL SHIFT (SEE SECT AA AA SHEET 1)
X1074
TORQUE BOXES
+Y
FWD
Y000
P425(R86)
LONGERON
AT STATION LINE PANEL DRIVE HINGE POINT IS FIXED TO LONGERON SO AS TO MOVE WITH LONGERON (SEE SECT AA AA SHEET 2)
AT STATION LINE, FWD AND AFT PANEL RECEIVE NO LONGITUDINAL SUPPORT ONLY RADIALLY SUPPORT ABOUT HINGE LINE, BOTH PANELS CAN SHIFT AS NECESSARY LONGITUDINALLY AFT PANEL DRIVE HINGED PER ◇ ABOVE (SEE SECT AA AA SHEET 2)
PANEL #1
#2
#3
#4
#5
#6
#7
HINGE LINE
X1085
X1580.55
PLAN VIEW-RADIATOR (1/50 SCALE)
DOOR END FRAME CAP ANGLE
SKIN STIFFENERS
EDP DOOR SKIN
EDP FUS SKIN
END FRAME CAP ANGLE & SHEAR BLADE FTG
FUSELAGE BULKHEAD SOCKET FITTING FOR DOOR SHEAR POP (NUMBER 2600 TBD)
Y200
SHEAR BLADE PATH OF TRAVEL, DOOR CLOSING MOTION
SKIN
STIFFENER
SHEAR BLADE
SOCKET FTG
FUSELAGE BULKHEAD REF PLANE
DOOR END FRAME WEB
X1074 AND 8-3
Y1845 FOR ±Y
Y-Yb2 Z-Zb2
X1085
RADIATOR PANEL END FRAME
STIFFENER
EQUATOR PIN
IN SECT B-2
RADIATOR TUBE
TO REACT PAYLOAD LOADS ⊥ TO Y-Y PLANE ONLY AT THIS STATION
(SEE VIEW BC AND SECT M-M)
◇ AT STATION LINE PANEL IS LATCHED TO FUSELAGE LONGERON ASSUMED NO RELATIVE LONGITUDINAL MOTION BETWEEN THE TWO
◇ NOMINAL PAYLOAD SUPPORT PINTS FOR BASE LINE PAYLOAD
◇ AT STATION LINE, FWD PANEL IS MECHANICALLY PINNED TO ADJACENT AFT PANEL TO PERMIT FWD PANEL EDP TO SHIFT LONGITUDINALLY RELATIVE TO AFT PANEL AFT PANEL IS LATCHED PER ◇ BELOW (TYPICAL 8 PLACES, SEE SECT AB-AB SHEET 2)
◇ AT STATION LINE PANEL IS LATCHED TO FUSELAGE LONGERON LATCH TO PERMIT RELATIVE LONGITUDINAL MOTION BETWEEN DOOR AND LONGERON (SEE SECT AB YB)
DOOR FIXED TO LONGERON AT THIS STATION SO AS TO MOVE WITH LONGERON (TYPICAL 10 PLACES, SEE SECT AB AB SHEET 3)
AT STATION LINE, FORWARD DOOR PANEL IS MECHANICALLY PINNED TO ADJACENT AFT PANEL TO PERMIT FWD PANEL EDP TO SHIFT LONGITUDINALLY RELATIVE TO AFT PANEL AFT PANEL IS HINGED PER △ ABOVE (SEE SECT AA AA SHEET 1)
AT STATION LINE, PANEL HAS HINGE LINES AND DRIVE MECHANISM FIXED TO LONGERON SO AS TO MOVE WITH LONGERON HINGE LINES AT DOOR PANEL CONNECTION TO SLIP LONGITUDINALLY RELATIVE TO PANEL (NO PANEL LONGITUDINAL LOAD PATH TO FUSELAGE LONGERON) SEE SECT AB AB
TO REACT PAYLOAD LOADS ⊥ TO Y-Y & Y-Z PLANES AT THIS STATION
PAYLOAD DOOR HINGE SIDE
Y425
Z
Y200
Z425
PANEL #1
#2
#3
#4
#5
#6
#7
#8
#9
#10
TORQUE TOO TYPICAL EACH DOOR CORNER
LATCH SIDE
PLAN VIEW-DOOR (1/50 SCALE)
Δ1
Δ3
Δ2
Δ3 CES
Δ4 A13
X1074
X1425
X1600
X1711
X1785
X1845
Z425
Z200
789 (65.75 FT)
SHEER VIEW-PAYLOAD DOOR (1/50 SCALE)
FWD
+Y
◇ DENOTES ALTERNATE PAYLOAD SUPPORT POINTS ADJACENT TO THIS STATION AND ALSO PAYLOAD HOLD DOWN CAPABILITY ADD OR PAYLOAD DOOR TO REACT PAYLOAD LOADS ⊥ TO X-Y PLANE AND ⊥ TO Y-Z PLANE (SEE SECT AA AA)

SECURITY CLASSIFICATION	DRAWING NUMBER	SH	REV
	2558T30083	3	1


FUSELAGE REF PLANE
LONGITUDINAL DIMENSIONAL VARIATIONS BETWEEN FUSELAGE REFERENCE POINTS CAUSE THIS ROD TO CHANGE AXIAL DIMENSION
SCHEMATIC CRUISE SUPPORT BRACKETS (TYP)
LATCH LOCKED
LATCH ACTUATION CRANK
LATCH LOCKED
LATCH ACTUATION ROD "PULL TO LOCK LATCH PUSH TO UNLOCK" (SHOWN LOCKED)
DIRECTION OF FUSELAGE STRETCH OR COMPRESSION
SCHEMATIC FOR PAYLOAD DOOR LATCH ACTUATOR SYSTEM ADJUSTMENT LINKAGES ARE PERMITTING FUSELAGE COMPRESSION OR STRETCH FROM LOCKING DOOR LATCHES (NUMBER REQUIRED TBD)
FUSELAGE FRAME REF PLANE
FUSELAGE LONGERON
DOOR LATCH LUG
LATCH HOOK
BEARINGS AT LATCH HOOK ATTACH POINTS PERMIT LATCH HOOK TO FOLLOW DOOR LUG AT LATCH LOCATIONS WHICH MUST ALLOW LONGITUDINAL SHIFT BETWEEN DOOR AND LONGERON BY HOOK ROTATION ABOUT THIS CENTERLINE (SEE RAGGED POSITIONS ON THIS SHEET, ZONE REF)
RADIATOR OPEN 145°
-Y
+Y
103 REF
1057 REF
2457
30 REF
90 REF
90 REF
2900
RADIATOR OPEN 180°
PAYLOAD DOOR OPEN 180°
VIEW LOOKING FWD (1/50 SCALE)
VIEW LOOKING AFT

REVISIONS			
LTR	ZONE	DESCRIPTION	DATE APPROVED

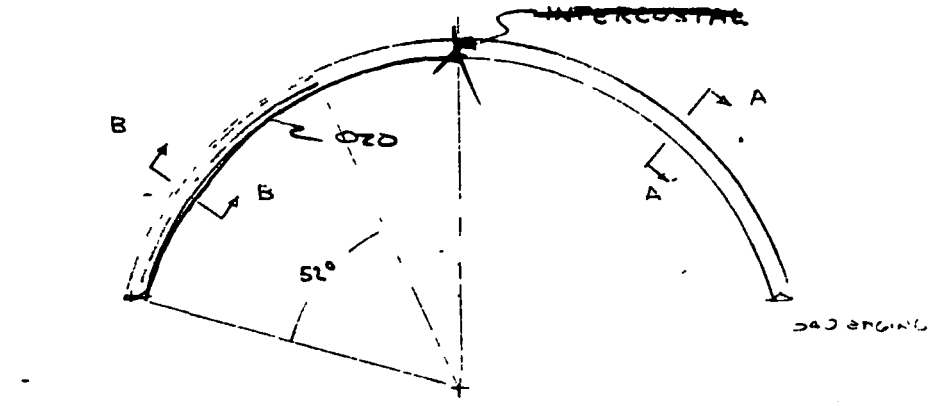
DR BERGHAUS	5-7-71	MCDONNELL DOUGLAS ASTRONAUTICS COMPANY – EASTERN DIVISION
CHK		MCDONNELL DOUGLAS CORPORATION
ENGR	5-6-71	DOOR ASSEMBLY-PAYLOAD COMPARTMENT-DELTA WING ORBITER
QA	5-7-71	
PROJ	5-7-71	
SIZE	CODE IDENT NO. 76301	255B730083
SCALE	WT	SHEET 8 OF 3

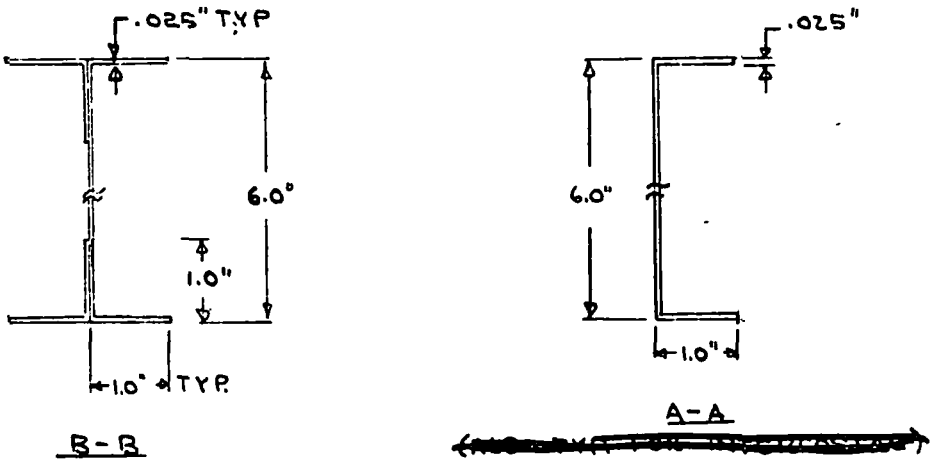
R. Lee

PAYLOAD COMPARTMENT DOOR COMPONENT THICKNESSES

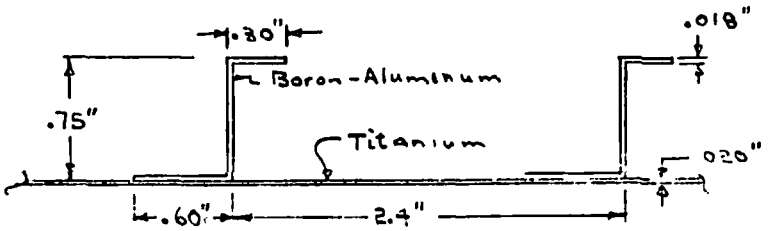
MATERIALS: TITANIUM ~ ALL COMPONENTS EXCEPT SKIN STIFFENERS
BORON-ALUMINUM ~ SKIN STIFFENERS

TYPICAL RIBS AT 20 IN SPACING





TYPICAL SKIN / STIFFENER ARRANGEMENT



J GABRISON	BODY	CARGO DOOR	1/

FS 1076 TO 1865

SHELL

280 * 789 * (020 + 003) * .164 = 833 LB

STIFFENERS

QTY = $\frac{280}{2.9}$ = 117

117 * 789 * 030 * 095 = 273 LB

FASTENERS

117 * 789 * 00073 = 68 LB

RIBS

QTY = 40

BASIC RIB x-SEC = 8 * 025 = .2 IN²

WT = 40 * 280 * .2 * 164 = 368 LB

BEEF UP x-SEC AA 025 = .1 IN²

95 * 40 * 1 * .164 = 62 LB

EDGE CLOSEOUT L = 10.5 +2" SEAL

125 * 040 * (789 + 280) 2 * .164 = 175 LB

FASTENERS

(280 * 40 * 4 + 1069 * 2 * 4) 00073 = 40 LB

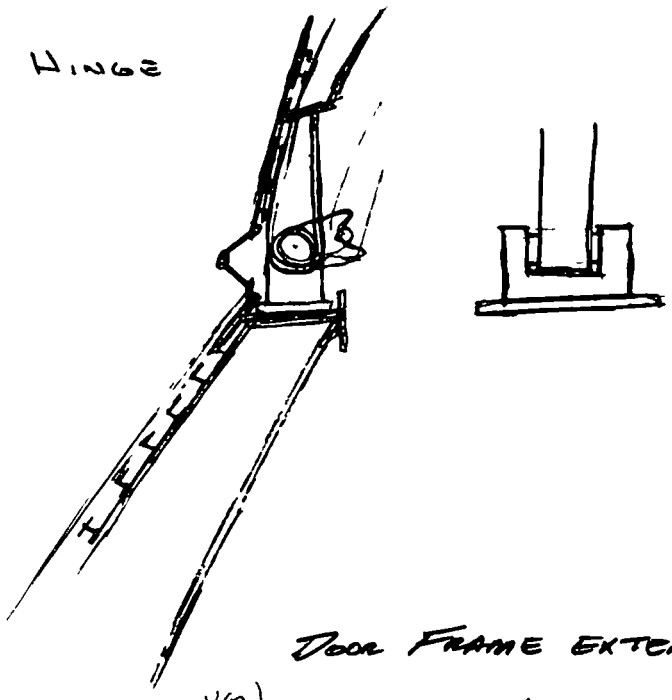
SUB TOTAL 1819 LB ITEM 65

THIS WEIGHT IS FOR LOCAL ACTUATOR OR JES AT EACH HINGE

PAYLOAD DOOR MECHANISM — 1051 LB

ITEM 6S.5

HINGES	537
DRIVE SYSTEM	100
LATCHES	144
DRIVE SYSTEM LATCHES	51
NON OPTIMUM	219



DOOR FRAME EXTENTION	1.5 LB
LONGERON / HINGE FTG	2.0 LB
LONGERON PAD	.5 LB
HINGE SEAL FAIRING	.3 LB
PIN	.2 LB
Redicton LOCK FITTING (2)	1.8
	4.5 LB EACH

TOTAL = 40 * 4.5 = 180 LB

LINK A 13 x 1.8 = 24 LB
LINK A 27 x 1.5 = 40 LB

244 LB

Payload Door Hinge 537

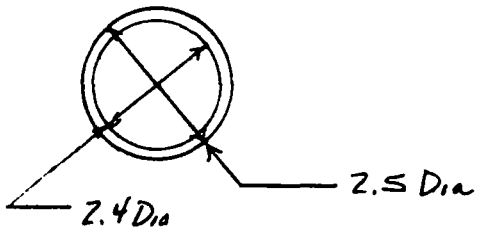
Harmonic Drive 96 lb
40@2.4lb*

* HDUC MODEL 32 Vendor Catalogue data

Hinge Fitting 244 Lb
Link A - 4.5 lb @ 40 180
Link B 64
1.5 @ 27
1.8 @ 13

Hinge Axis Drive

Torque Tube TITANIUM



$$Weight = .160 \times \frac{\pi}{4} (2.5^2 - 2.4^2) \times 789 = 48 Lb$$

SUPPORT TUBE – TITANIUM

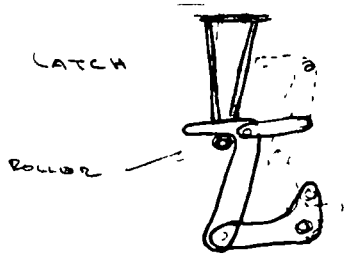
$$Wt = 160 \times \frac{\pi}{4} (5.0^2 - 4.9^2) \times 789 = 89 Lb$$

Payload Door & Radiator Drive System. 100 LB

Motors & Mounting	20
Power Transfer & Manual Drive	10
Clutches (2)	20

Transmission System

Radiator Sill to Motor 73.619 ft'	14
Door Sill to Motor 73.620 ft'	15
Right Angle Gear Boxes (2)	21



ROLLER SUP'T ASSY
12 x .25 x .164 = 5 LB

LATCH HOOK
12 x .25 x .160 = 5 LB

LINKAGE
24 x 25 x .160 = 10 LB

SNUBBER BLOCKS .25 LB

TOTAL 2.25 LB

Payload Door Latches 144 Lb

Latches 40 @ 2.25 90 Lb

Drive - 54 Lb

Tube - Titanium 48 Lb
Same as Reduntan Drive

Supports 6 Lb
8 @ .75#/ea

Payload Door Latches Drive System 51 Lb

Motors & Mounting 20 Lb
Power Transfer Manual Drive 10 Lb
Transmissional System
Door Latch Sill to Motor 13 @ 10 7 Lb
Gear Boxes (2) 14 Lb

1	J GARRISON		DWO 050-F	Y

SEC LH$_2$ TANK ACCESS DOOR FS 613 - 886 L = 288

613 - 700 L = 93

(91 + 92) $\frac{93}{144}$ = 118 FT^2

700 - 800 L = 105

(92 + 95) $\frac{105}{144}$ = 136 FT^2

800 - 886 L = 90

(95 + 95) $\frac{90}{144}$ = 119 FT^2

373 FT^2

UPPER SKIN FS 886 - 1076

886 - 900 L = 17

(95 + 95) $\frac{17}{144}$ = 22

900 - 929 L = 31

(95 + 108) $\frac{31}{144}$ = 44

929 - 1000 L = 75

(108 + 131) $\frac{75}{144}$ = 125

1000 - 1076 L = 76

(131 + 140) $\frac{76}{144}$ = 143

334 FT^2

3/

FOR THE FWD UPPER SKIN AND ACCESS DOOR ASSUMG THE SAME UNIT WEIGHT AS THE CARGO DOOR

$$\frac{1819 \text{ LB}}{1582 \text{ FT}^2} = 1.2 \text{ PSF}$$

UPPER SKIN

334 * 1.2 = 400 LB @986 ITEM 35

TANK ACCESS DOOR

373 * 1.2 = 448 @ 750 ITEM 66

SPEED BRAKES

WEIGHT DERIVED BY EMPERICAL CORRELATION FROMM MAC 747 WEIGHT ESTIMATION DOCUMENT

$WT = .6\,(\text{AREA SPEED BRAKE})^{.6}\,(\text{LIMIT LOAD})^{.3}(\text{QUANTITY})$

AREA = 90 * 80 = 7200 IN^2

LOAD = 50 * 253 = 12650 LB

$WT = .6\,(7200)^{.6} * (12.65)^{.3} * 2$

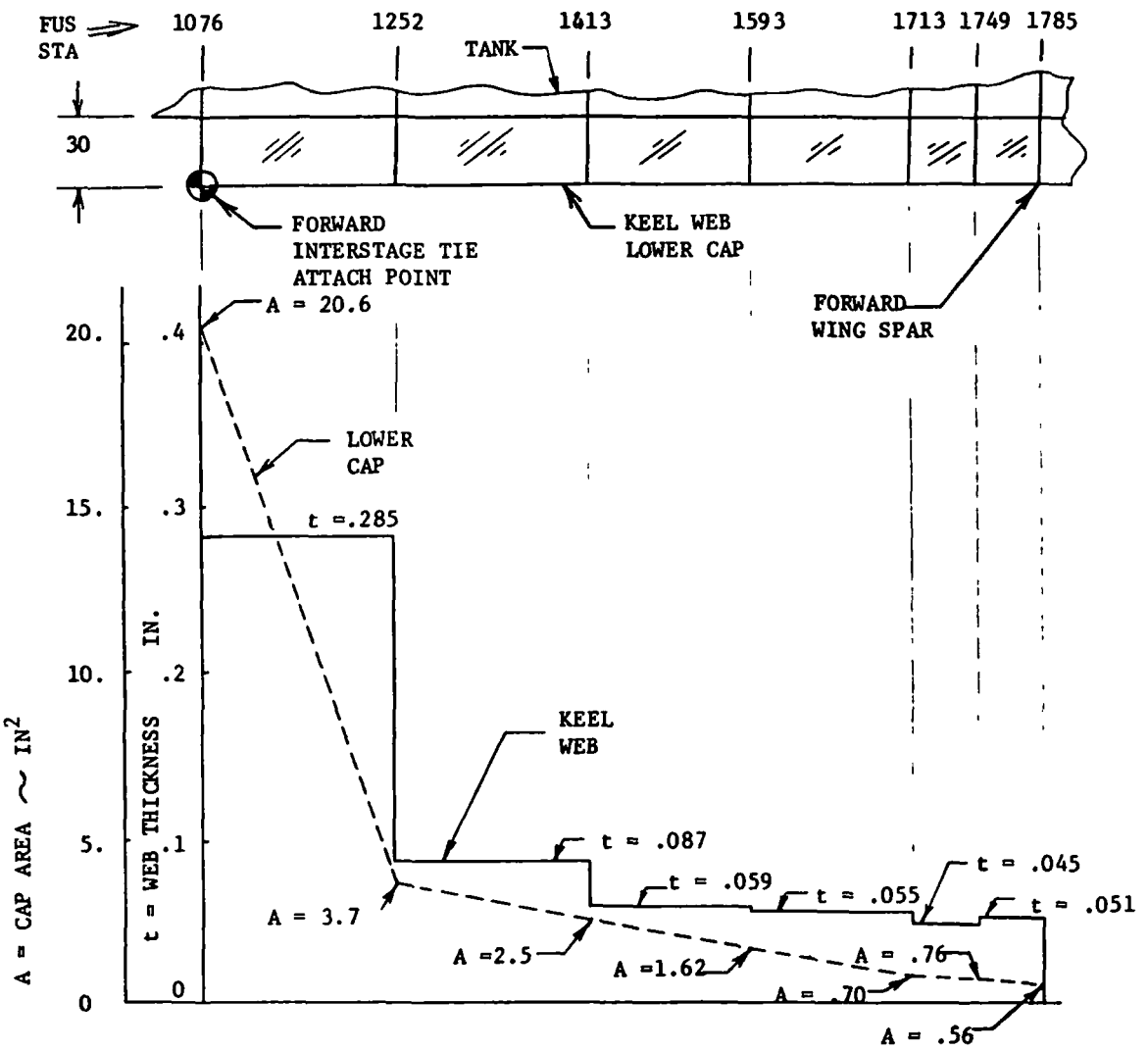
= 534 LB ITEM 77

MDC E0308 30 June 1971	Space Shuttle Program – Phase B Final Report TECHNICAL SUMMARY	PART II-2 ORBITER

KEEL WEB SIZING SUMMARY

NOTE:

1. BASED ON INTERNAL LOADS SHOWN IN REPORT
2. WEB IS ASSUMED TO HAVE VERTICAL STIFFENERS EVERY 10 INCHES
3. $\bar{t}$ WEB = 1.3 t



Web

BS 1076 - 1252

Web 285 *30 * 176 * .164	=	247 LB
STIFF 247 *.3	=	74 LB
TOTAL		321 LB

BS 1252 - 1413

Web 087 *30 * 161 * .164	=	69 LB
STIFF 69 *.3	=	21 LB
TOTAL	=	90 LB

BS 1413 - 1593

Web 059 *30 *180 *.164	=	52 LB
STIFF 52 *.3	=	16 LB
TOTAL		68 LB

BS 1593 - 1713

Web 055 *30 * 120 *.164	=	33 LB
STIFF 33 *.3	=	10 LB
TOTAL		43 LB

BS 1713 - 1749

Web 045 *30 * 36 *.164	=	8 LB
STIFF 8 * 3	=	2 LB
TOTAL		10 LB

BS 1749 - 1785

Web 051 *30 *36 *.164	=	9 LB
STIFF 9 *.3	=	3 LB
TOTAL		12 LB

CAD

BS 1076 - 1252

$176(20.6 + 3.7)\frac{1}{2} * .164$ = 357 LB

BS 1252 - 1413

$161(3.7 + 2.5)\frac{1}{2} * .164$ = 82 LB

BS 1413 - 1593

$180(2.5 + 1.62)\frac{1}{2} * .164$ = 61 LB

BS 1593 - 1713

$120(1.62 + .76)\frac{1}{2} * .164$ = 23 LB

BS 1713 - 1749

$36(.76 + .70)\frac{1}{2} * .164$ = 4 LB

BS 1749 - 1785

$36(.70 + 52)\frac{1}{2} * .164$ = 4 LB

Web	544
Caps	526
28 % Non Opt	300
	1370 LB

ITEM 83

TABLE 2.4-1

DETAIL WEIGHT STATEMENT

			Weight-lbs	Page
2.4	Induced Environment Protection		32847	2.4-5
	Thermal Protection		[29861]	
	Leading Edge/Nose Cap		(350)	
	Wing L.E & Strake	5272*		
	Body Flap L.E.	N/A		
	Vertical Tail L.E.	731*		
	Body-Nose Cap	350		
	Surface Protection		(27625)	
	Wing		8330	
	Columbium	2211		
	Hastelloy X	3713		
	Insulation & Bagging	2406		
	Horizontal Tail/Body Flap		752	
	Hastelloy	518		
	Insulation & Bagging	234		
	Body		18543	
	Columbium	4545		
	Hastelloy X	3809		
	Rene 41	1244		
	Inconel 718	1007		
	Titanium	1046		
	Insulation & Bagging	6892		
	Base Heat Protection		(1886)	
	Base Heat Protection	1100		
	Main Engine Heat Protection	786		
	Contingency		[2986]	

* Wing and Tail Leading Edge weights are shown here for reference only. They are included in the wing and tail group respectively.

2.4 Induced Environment Protection Weight Substantiation - The induced environment protection weights, presented in Table 2.4-1, were determined by detailed analysis of the Thermal Protection System (TPS) established by the design thermal environment which resulted from the trajectory, presented in Figure 2.4-1, which is a duplicate of Figure 5.2.2.7-1, Delta Orbiter Reentry trajectory, from Reference 1, (Reference 1 - Report MDC-E0308 Part 11-1, Technical Summary.) The design temperatures also present in Figure 5.2.2.7-3 of Reference 1 are repeated here in Figure 2.4-2. These data along with pressure data established TPS thickness and material requirements. The correlation of temperature and pressure to TPS thickness and material requirements, and the resulting unit weights, is presented in Reference 2. (Reference 2 - Report MDC-E0308 Space Shuttle Program - Phase B Final Report - Technical Summary - Part 11-2 Orbiter.)

The TPS detail weight analysis consists of evaluating the weight of Leading Edges, Surface Protection and the Base Heat Protection. The typical analysis envolves to the simple multiplication of wetted surface area by the TPS unit weights. The Induced Environment Protection Weight Calculation is presented in Table 2.4-2.

There is 39450 pounds in the total of Induced Environment Protection (32847 lb), Wing Leading Edge and Strake (5799 lb.) and Tail Leading Edge (804 lb.) for the Analysis Vehicle. This 39450 pounds is 5244 pounds above comparable data for the Final Design Baseline. This decrease was indicated by 2850 lb. TPS weight decrease presented in MP 9 and MP 10. The final design baseline incorporated lower temperature data, based upon new test data, that was not available at the issuance of either MP 9 or MP 10. These temperature data are the reason for the Final Design Baseline TPS and Leading Edges being even lighter than predicted by MP 10.

The summary of the metalic shingle unit weight/temperature/vehicle station data is presented in Table 2.4-2. This data is a copy of that presented in Section 2.3.3- of Reference 2.

The TPS also includes insulation and insulation bagging along with the metallic shingles. The insulation and bagging unit weights data for the Delta Orbiter are presented in Figures 2.4-3 and 2.4-4. These data are also presented in Section 2.3.3- of Reference 2.

The TPS surface protection units weights, metallic shingle and insulation from Reference 2 are presented in Table 2.4-2 and Figures 2.4-3, and 2.4-4. These data are the basic unit weight imputs for the TPS surface protection evaluation.

The metallic shingle unit weight of Reference 2, are arrived at by evaluating nominal weight of the premium stock defined by the Reference 2 evaluation. This data has not considered the normal occurance of sheet stock being heavier than nominal by an amount equivalent to fifty percent of the plus tolerance.

The significance of this is apparent from the sheet stock tolerance data presented in Figures 2.4-5 and 2.4-6. The probability of thousands of pounds of nonoptimum weight, occuring with the usage of standard stock, has established the premium stock with its lower tolerance, also presented in Figures 2.4-5 and 2.4-6, as the standard for Shuttle Orbiter TPS.

FIGURE 2.4-1 DELTA ORBITER REENTRY TRAJECTORY

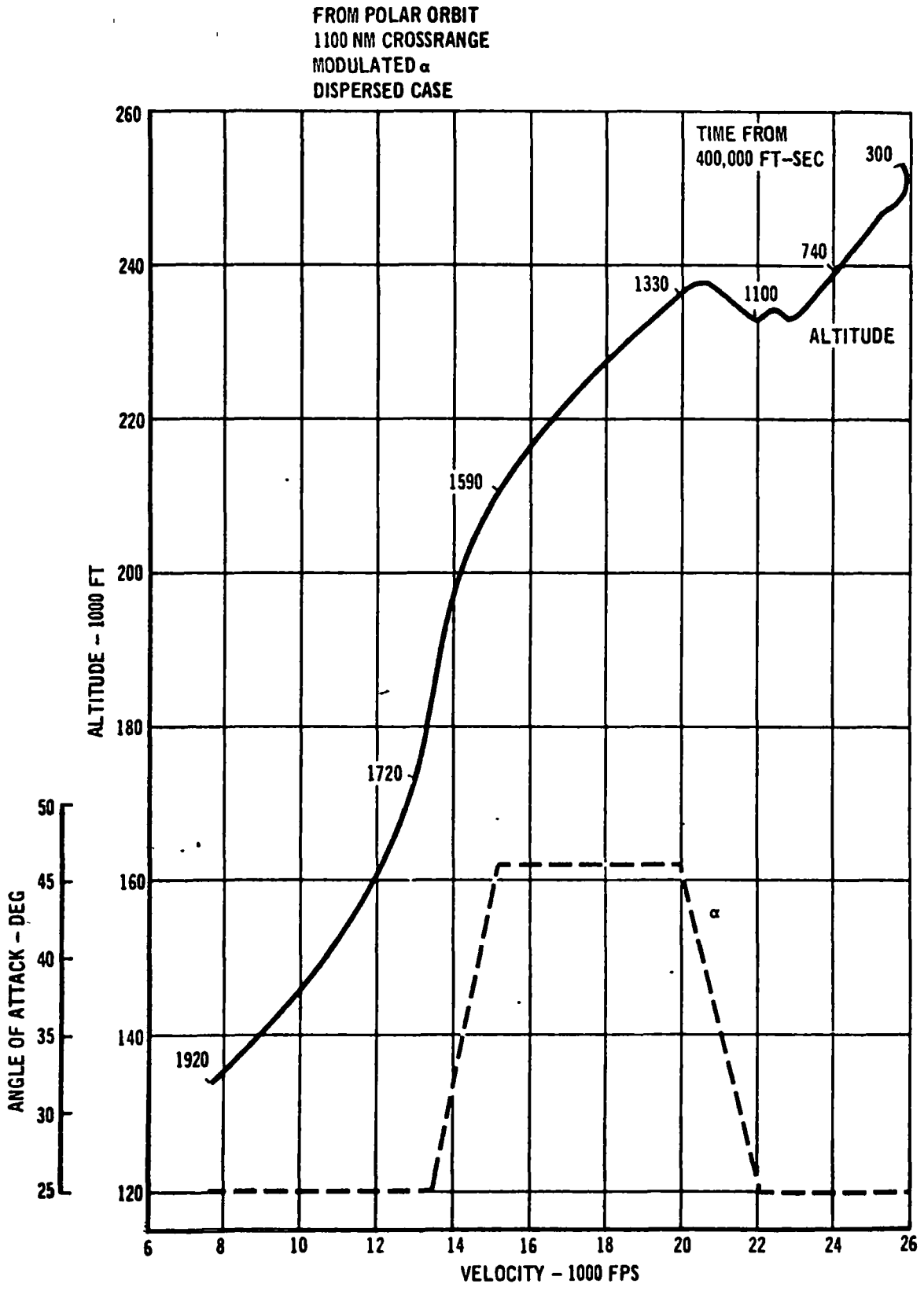
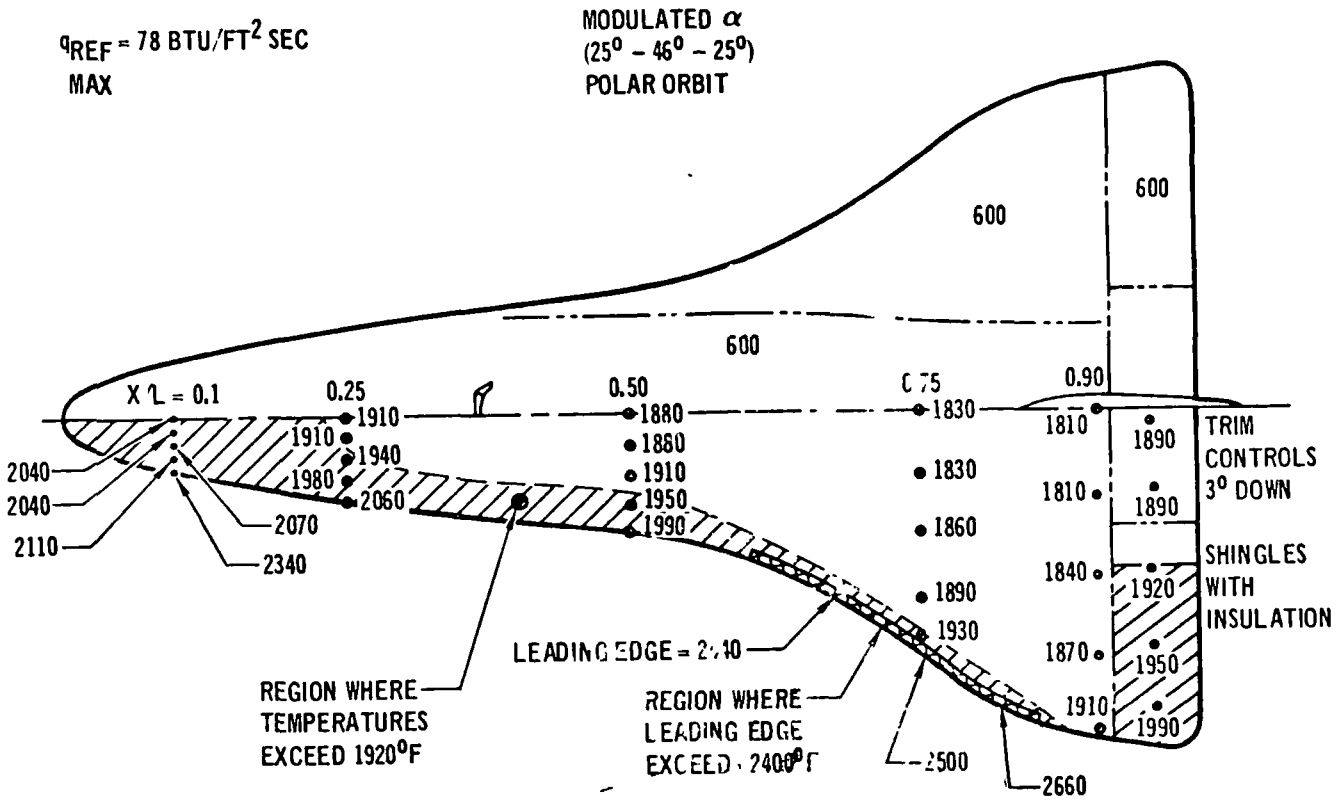


FIGURE 2.4-2

DELTA ORBITER DESIGN TEMPERATURES



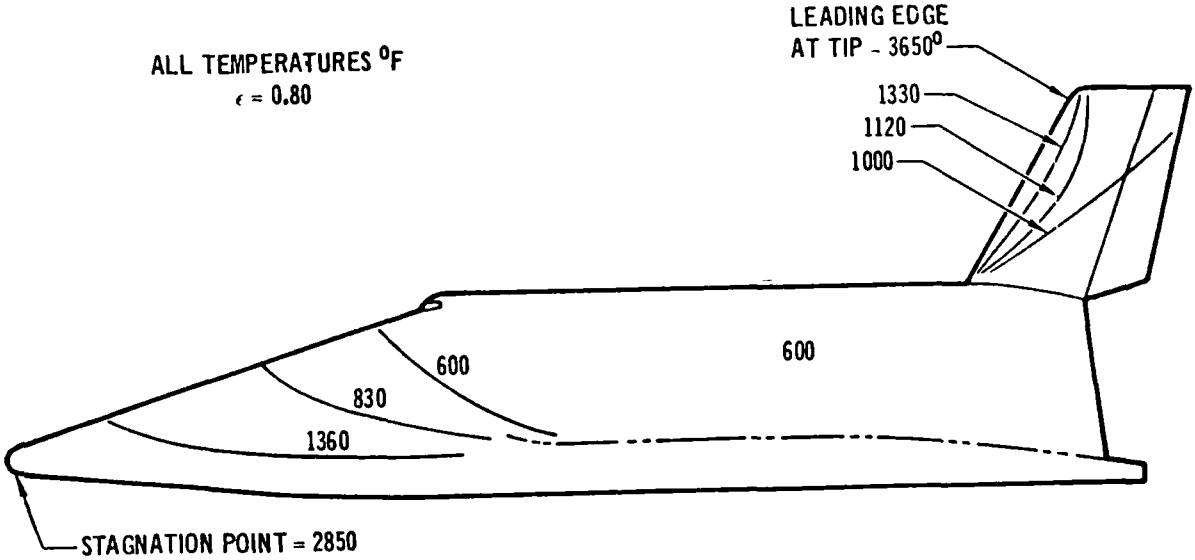


TABLE 2.4-2

INDUCED ENVIRONMENT PROTECTION WEIGHT CALCULATION

	AREA Ft²	INSULATION PSF	INSULATION Lb	SHINGLE PSF	SHINGLE Lb	TOTAL Lb
TOTAL VEHICLE -TPS	23396		11418		18443	29861
LEADING EDGE / NOSE CAP	[1405		[—]		[350]	[350]
BODY	(70)				(350)	(350)
CARBON-CARBON	70	Incl.	—	5.00	350	350
WING-LE & STRAKE	(1161)		(945*)		(4327*)	(5272)
CARBON-CARBON L.E	389	Incl	—	4.21	1637*	—
Cb L.E	129	Incl.	—	3.95	510*	—
Cb STRAKE	643	1.47	945*	3.39	2180*	—
HORIZONTAL TAIL (B.F.)	N/A		(—)		(—)	(—)
VERTICAL TAIL	(174)		(—)		(731*)	(731*)
CARBON-CARBON L.E	174	Incl.	—	4.20	731*	
SURFACE PROTECTION	[19993]		[9532]		[18093]	[27625]
BODY	(12086)		(6892)		(11651)	(18543)
BOTTOM	(3702)		(4820)		(8354)	(13174)
Cb 227-400	234	1.52	356	4.09	957	1313
Cb 400-840.5	916	1.39	1273	3.39	3105	4378
Cb 840.5-1400	198	1.38	273	2.44	483	756
HAST 900-1400	943	1.34	1264	1.63	1537	2801
HAST 1400-1865	1070	1.32	1412	1.61	1723	3135
HAST 1865-2013.1	341	.71	242	1.61	549	791
SIDE & TOP	(8384)		(2072)		(3297)	(5369)
RENE 41	895	.78	698	1.39	1244	1942
INCONEL 718	746	.35	261	1.35	1007	1268
TITANIUM	1341	.14	188	0.78	1046	1234
HOT STRUCTURE	2808	.20	562	—	—	562
HOT STRUCTURE	2594	.14	363	—	—	363
WING	(6388)		(2406)		(5924)	(8330)
BOTTOM	(2309)		(1685)		(3713)	(5398)
HAST - 80%	1847	.73	1348	1.57	2900	4248
HAST - 20%	462	.73	337	1.76	813	1150
TOP	(2196)					
HOT STRUCTURE	2196	—	—	—	—	—
ELEVON TOP	(946)					
HOT STRUCTURE	946	—	—	—	—	—
ELEVON BOTTOM	(937)		(721)		(2211)	(2932)
Cb	937	.77	721	2.36	2211	2932
BODY FLAP	(454)		(234)		(518)	(752)
BOTTOM	(320)		(234)		(518)	(752)
HAST	320	.73	234	1.62	518	752
TOP	(134)					
HOT STRUCTURE	134	—	—	—	—	—
VERTICAL TAIL	(1065)					
HOT STRUCTURE	1065	—	—	—	—	—
BASE	[1998]		[1886]		[—]	[1886]
HOT STRUCTURE	1000	1.10	1100	—	—	1100
ENGINE	478	1.10	526	—	—	526
ENGINE	520	0.50	260	—	—	260
CONTINGENCY	N/A		[1142]		[1844]	[2986]
INDUCED ENVIRONMENT						32847

* WING AND TAIL LEADING EDGE WEIGHTS ARE SHOWN FOR REFERENCE ONLY. THEY ARE INCLUDED IN THE WING AND TAIL GROUP RESPECTIVELY.

TABLE 2.4-3

SUMMARY OF STRUCTURAL TPS UNIT WEIGHTS VS VEHICLE LOCATION

Location	X/L Range	Metallic TPS Material	Critical Condition (Ult.Δ p/temp)	Unit Weight (PSF)
Fuselage Lower Surface	0 - .13	FS-85 Colum.	8.6 psi/R.T.	3.72
	.13 - .35	FS-85 Colum.	5.4 psi/R.T.	3.08
	.13 - .35	Hastelloy X	5.4 psi/R.T.	1.73
	.35 - .63	FS-85 Colum.	±1.4 psi/R.T.	2.216
	.35 - .63	Hastelloy X	+.75 psi @ 1880°	1.476
	.63 - .87	Hastelloy X	+.75 psi @ 1830°	1.462
	.87 - 1.00	Hastelloy X	+.75 psi @ 1810°	1.462
Fuselage Sides and Top	.10	Rene '41	±1.4 psi/R.T.	1.262
	.25	Inconel 718	±1.4 psi/R.T.	1.222
	.50	Titanium	±1.4 psi/R.T.	.71
	.75	Titanium	±1.4 psi/R.T.	.71
Wing Lower Surface	0 - .80 Exposed semi-span	Hastelloy X	+.75 @ 1875°	1.43
	.80 - 1.0 Exposed semi-span	Hastelloy X	±3.0 psi/R.T.	1.60
Elevon Lower Surface		Hastelloy X	+.75 @ 1890	1.47
		FS-85 Colum.	±1.4 psi @ R.T.	2.15
Wing and Fin Leading Edges (2)		Carbon/carbon	±3.0 psi/R.T.	3.31
		FS-85 Columbium	±3.0 psi/R.T.	2.85

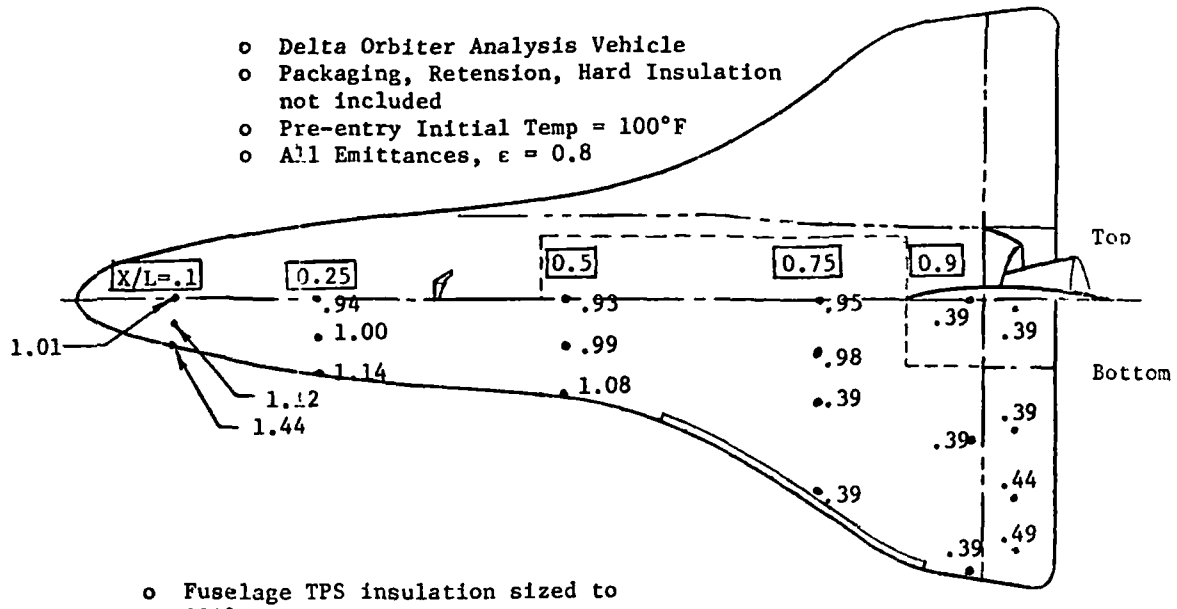
(1) Includes panel, transverse support beam, retainer, support struts, drag links and end fittings.

(2) Considered structure in mass properties accounting; not TPS.

FIGURE 2 4-3

DELTA ORBITER INSULATION

UNIT WEIGHT, PSF



- o Fuselage TPS insulation sized to 300°F maximum substructure temperature
- o Wing TPS insulation (including carry through) sized to 600°F optimum design temperature

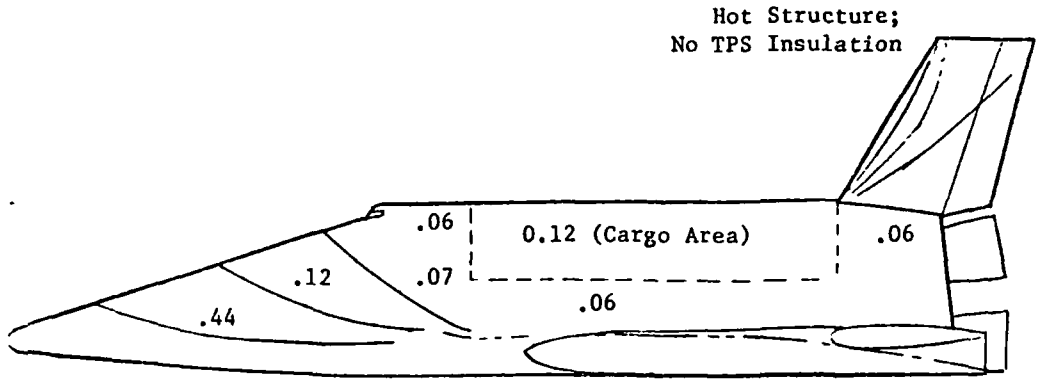


FIGURE 2 4-4

DELTA ORBITER INSULATION

PACKAGING UNIT WEIGHTS, PSF

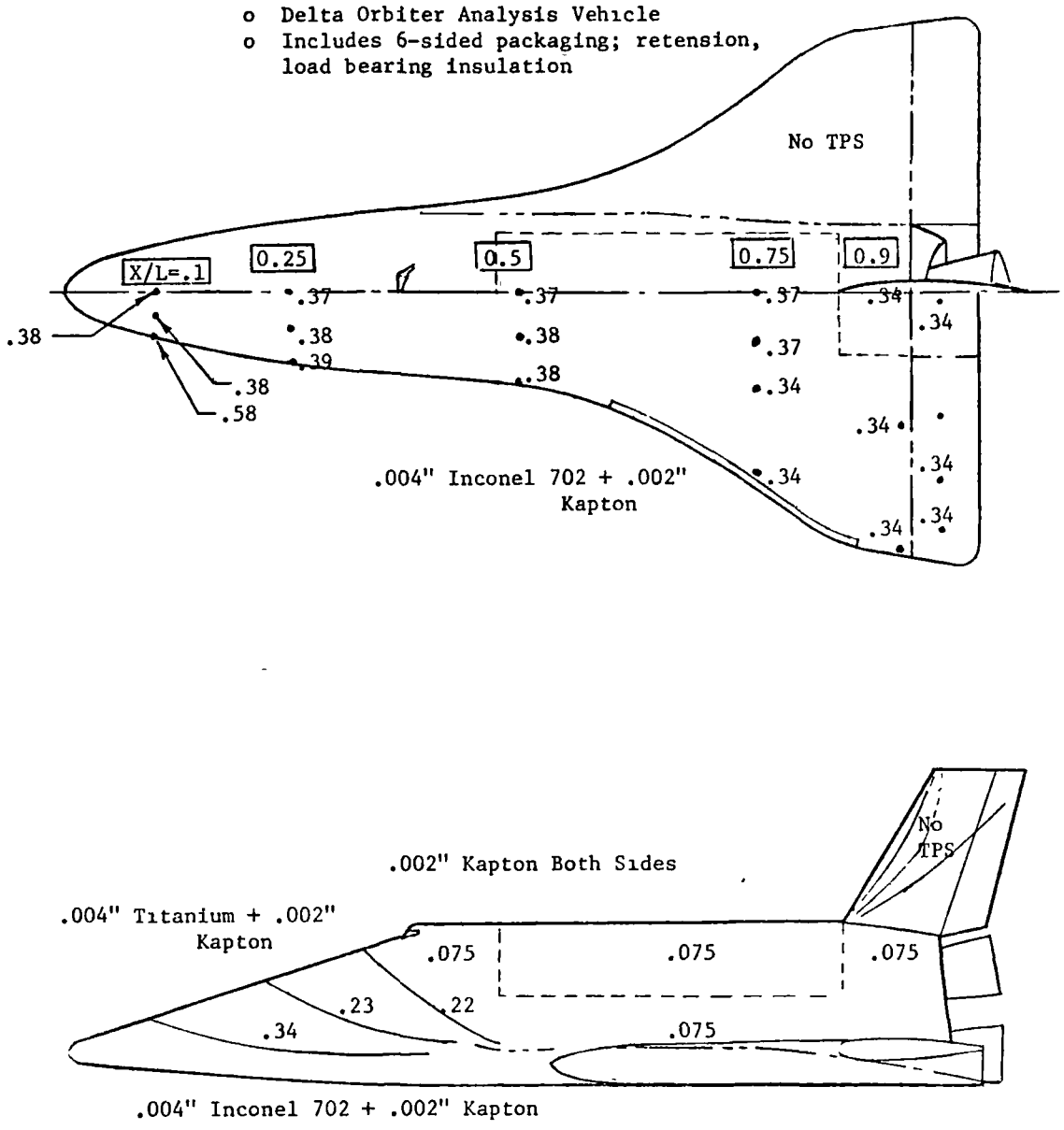


FIGURE 2.4-5 SHEET TOLERANCE (IN) -VS- GAGE (IN)

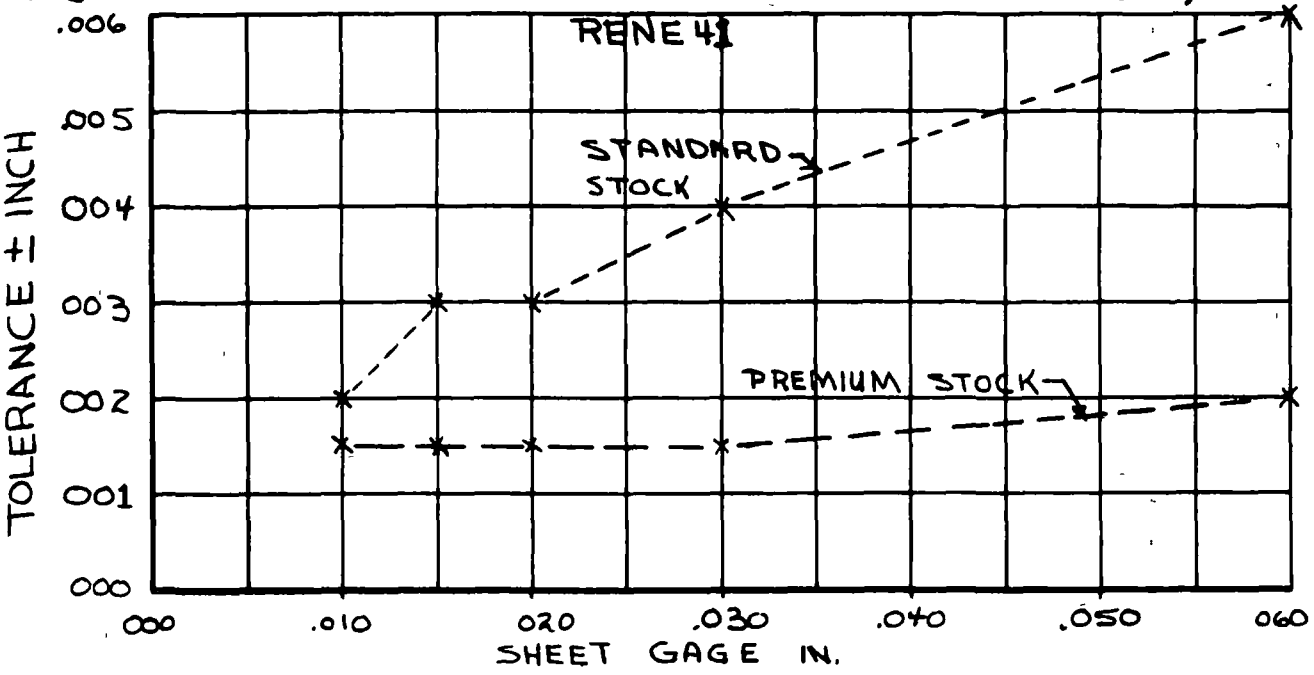


FIGURE 2.4-6 SHEET TOLERANCE (PERCENT) VS - GAGE (IN.)

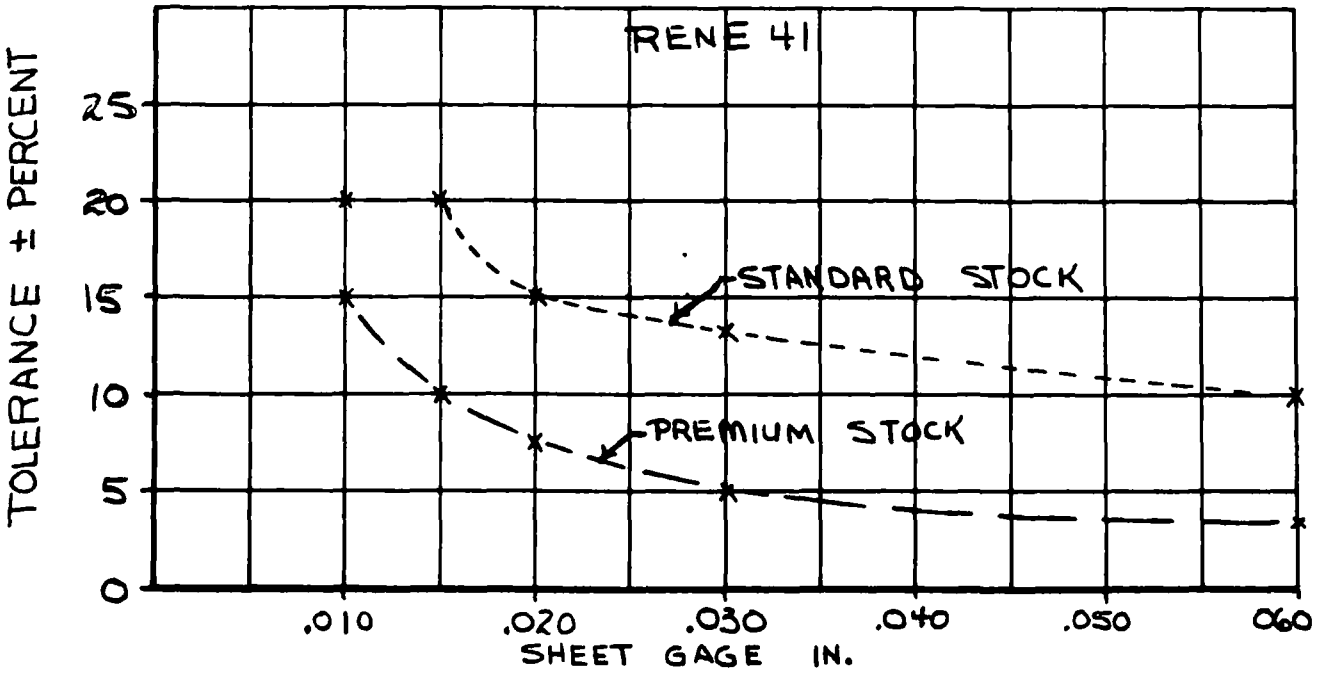


Table 2.4-4 establishes that structural components are most always above nominal. This data indicates that standard sheet metal is heavier than nominal by 14 to 50 percent of the allowable positive tolerance. The use of premium gage stock will significantly decrease the weight involved in the positive tolerance but should not alter the percent of plus tolerance that will normally occur. Therefore unit weights for all the surface protection shingles (structural TPS) and the columbium strake portion of the wing leading edge of the TPS weight calculation are ten percent above those presented in Table 2.4-3.

The TPS weight evaluation, multiplication of area by unit weight, does not account for the design complexities that will surely occur when the drawings are released for fabrication. Typical of the complexities being considered here are edging for access panels and doors and the prevention of galvanic action at shingle material changes. A ten percent contingency has been included for these complexities.

The TPS area data are determined through an automated loft type evaluation. The Orbiter lines drawing with TPS material distribution is processed through a line tracer which automatically records coordinate data for the TPS. From this coordinate data, the wetted area of the TPS is computed. Typical output data is shown in Table 2.4-5. Since there are more than fifty pages of this data it has been summarized in Table 2.4-6. The plot of the different TPS materials zones is presented in Figure 2.4-7.

This area evaluation included area for Wing Leading Edges, Body Nose Cap, and Surface Protection. The other TPS area data, Vertical Tail, and Base have been evaluated from detail calculation of released drawings. The Vertical Tail leading edge evaluation included the determination of the perimeter at several horizontal stations of the tail. The Tail leading edge area is then the total of the average perimeter multiplied by the true length of leading edge.

Station	Perimeter Inch	True Length (Inch)
Base	80	0
60%	62	230
Tip	52	383

$$\text{Area } \left(\frac{80 + 62}{2}\right)\frac{230}{144} + \left(\frac{62 + 52}{2}\right)\frac{153}{144} = 174 \text{ Ft}^2$$

The 1065 ft^2 of vertical tail hot structure was determined by subtracting the 174 leading edge area from the 1139 Ft^2 area of the total tail. The 1139 Ft^2 area was established by a loft evaluation.

TABLE 2.4-4 ACTUAL TOLERANCE DATA

ITEM	STOCK GAGE (IN)	CALCULATED WEIGHT Lb	CALCULATED TOLERANCE ± Lb	CALCULATED TOLERANCE ±%	ACTUAL No OF ITEMS	ACTUAL MEAN Lb	ACTUAL TOLERANCE ± Lb(3σ)	ACTUAL TOLERANCE ±%	TOL ACT/CAL %
A	.010 ± .002	4.70	0.94	20	5	4.90	0.96	4.2	21
B	.016 ± .003	10.29	1.93	18.8	5	11.25	0.78	7.3	50
C	.016 ± .003	8.58	1.61	18.8	6	8.99	1.05	4.8	26
D	.032 ± .004	16.40	2.05	12.5	5	16.68	0.78	1.7	14

255BJ0050

THE FOLLOWING DATA INCLUDES BOTH SIDES OF THE VEHICLE

SECTION ML PARAMETERS BODY STA.108.342 TO BODY STA.116.676

TABLE 2.4-5
TYPICAL LOFT DATA

	PERIMETER AT BS 108.342 FT (1300 INCHES)	PERIMETER AT BS 116.676 FT (1400 INCHES)	WETTED AREA FOR THIS SECTION	WETTED AREA SUMMATION FROM BS 89.674
ZONE 1	30.120035	37.632075	282.503948	727.940658
ZONE 2	14.542089	13.160631	118.284241	426.710443
ZONE 3	6.143446	9.374840	64.969436	163.433587
ZONE 4	16.800045	17.474397	142.849620	436.789579
ZONE 5	44.382942	44.089938	368.699344	1191.834650
ZONE 6	0.0	0.0	0.0	0.0
ZONE 7	0.0	0.0	0.0	0.0
ZONE 8	0.0	0.0	0.0	0.0
ZONE 9	0.0	0.0	0.0	0.0
TOTALS	111.988558	121.731880	977.306589	2946.708918

VOLUME FOR THIS SECTION 5932.240248

SUMMATION OF VOLUME FROM BS 89.674 50743.619344

XSECT AREAS
695.385 AT BS108.342
723.160 AT BS116.676

NOTE--ALL UNITS ARE FT,SQ.FT.OR CU.FT

TABLE 2.4-6, Page 1 of 4

TPS AREA - SQ. FT.

Body Station Fwd	Body Station Aft	Total	CARBON CARBON (1)	HAST (2)	Cb (3)	L.E. (4)	Hot Str (5)	RENE (6)	INCONEL (7)	Ti. (8)	Hot Struc (9)
177.0	227.0	70	NOSE CAP 70								
227.0	250.0	43			Body Btm 25			Body Top & Side 18			
250.0	300.0	114			Body Btm 61			Body Top & Side 53			
300.0	400.0	314			Body Btm 148			Body Top & Side 166			
400.0	460.0	236			Body Btm 102			Body Top & Side 134			
460.0	500.0	172			Body Btm 70			Body Top & Side 45	Body Top & Side 57		
500.0	547.6	227			Body Btm 91			Body Top & Side 55	Body Top & Side 81		
547.6	591.2	221			Body Btm 86			Body Top & Side 34	Body Top & Side 101		
591.2	600.0	46			Body Btm 18			Body Top & Side 7	Body Top & Side 21		
600.0	634.8	191			Body Btm 72			Body Top & Side 28	Body Top & Side 91		
634.8	657.5	131			Body Btm 49			Body Top & Side 19	Body Top & Side 63		
657.5	700.0	254			Body Btm 93			Body Top & Side 46	Body Top & Side 62		Body Top & Side 53
700.0	705.0	32			Body Btm 12			Body Top & Side 6	Body Top & Side 6		Body Top & Side 8
Sub-Totals 177.0	227.0	NOSE CAP	70								
227.0	400	Body Bottom — Cb			234						
400.0	705.0	Body Bottom — Cb			593						
177.0	705.0 Total-Page	2051	70		827			611	482		61

TABLE 2.4-6, Page 2 of 4

TPS AREA - SQ. FT.

Body Station			C-C	Hast	Cb	C-C	Hot Str	Rene	Inconel	Ti.	Hot Str
Fwd	Aft	Total	1	2	3	4	5	6	7	8	9
705.0	750.0	287			Body BTM 105			Body Side & Top 25	Body Side & Top 54		Body Side & Top 103
750.0	800.0	335			Body BTM 118			Body Side & Top 30	Body Side & Top 52		Body Side & Top 135
800.0	840.5	286			Body BTM 100			Body Side & Top 24	Body Side & Top 45		Body Side & Top 117
400 0	840.5	Body	Page 1 Bottom - Cb		(593) 916						
840.5	886.0	325			Body BTM 117			Body Side & Top 27	Body Side & Top 51		Body Side & Top 140
886.0	900.0	108			Body BTM 36			Body Side & Top 8	Body Side & Top 8	Body Side & Top 9	Body Side & Top 47
900 0	929.0	229		Body BTM 31	Body BTM 45			Body Side Top 18	Body Side Top 15	Body Side Top 17	Body Side Top 103
929 0	1000.0	566		Body BTM 114	STRAKE 81			Body Side Top 40	Body Side Top 36	Body Side Top 32	Body Side Top 263
1000.0	1005 0	42		Body BTM 8	STRAKE 6			Body Side Top 3	Body Side Top 3	Body Side Top 3	Body Side Top 19
1005.0	1076 0	592		Body BTM 114	STRAKE 98			Body Side Top 25		Body Side Top 94	Body Side Top 261
1076.0	1100 0	205		Body BTM 46	STRAKE 30			Body Side Top 8		Body Side Top 31	Body Side Top 90
1100.0	1195.0	819		Body BTM 175	STRAKE 128			Body Side Top 38		Body Side Top 124	Body Side Top 354
1195.0	1200.0	47		Body BTM 11	STRAKE 8			Body Side Top 2		Body Side Top 7	Body Side Top 19
Sub-Totals 705.0	840.5	Body	Bottom - Cb		323						
840.5	929.0	Body	Bottom - Cb		198						
929.0	1200.0	STRAKE			351						
Total - Page 2		2851		499	572			248	264	317	1651

TABLE 2.4-6, Page 3 of 4

TPS AREA - SQ. FT.

Body Station			CC	Hast	Cb	CC	Hot Str	Rene	Inconel	Ti	Hot Str
Fwd	Aft	Total	1	2	3	4	5	6	7	8	9
1200.0	1274.4	669		Body Btm 154	STRAKE 112			Body Side Top 36		Body Side Top 97	Body Side Top 270
1274.4	1300.0	237		W&B BTM 62	STRAKE 33		Wing Top 14			Body Side Top 35	Body Side Top 93
1300.0	1400.0	976		W&B BTM 282	STRAKE 118		Wing Top 65			Body Side Top 143	Body Side Top 368
1400.0	1425.0	259		W&B BTM 80	STRAKE 29		Wing Top 21			Body Side Top 39	Body Side Top 92
1425.0	1500.0	828		W&B BTM 287		WING L.E. 71	Wing Top 81			Body Side Top 112	Body Side Top 277
1500.0	1600.0	1243		W&B BTM 453		WING L.E. 89	Wing Top 176			Body Side Top 156	Body Side Top 369
1600.0	1700.0	1410		W&B BTM 538		WING L.E. 79	Wing Top 206			Body Side Top 160	Body Side Top 364
1700.0	1800.0	1613		W&B BTM 634		WING L.E. 75	Wing Top 372			Body Side Top 168	Body Side Top 364
1800.0	1865.0	1154		W&B BTM 460		WING L.E. 49	Wing Top 291			Body Side Top 116	Body Side Top 238
1865.0	1900.0	662		W&B BTM 264		WING L.E. 26	Wing Top 179				Body Side Top 193
1900.0	2000.0	2005		W&B BTM 787	WING LE 64		Wing Top 579				Body Side Top 575
2000.0	2021.5	452		W&B BTM 163 Body Flap 19	WING LE 14		Wing Top 149				Body Side Top 107
Sub-Total WING BODY	BOTTOM BOTTOM			2309. 1855.							
BODY WING	FLAP STRAKE	/ TOP		190.	292.		2196				
WING BODY	LE SIDE,	TOP			78.	389.		36		1024	2310
Total-Page 3		11509		4183	370.	389.	2196	36.		1024.	2310.

TABLE 2.4-6, Page 4 of 4

TPS AREA - SQ. FT.

Body Station			CC	Hast	Cb	C-L LE.	Mt Strut	Rene	Inconel	T..	HotStru
Fwd	Aft	Total	1	2	3	4	5	6	7	8	9
2021 S	2100.0	1634		Body Flap 169	L.E. S1 Elevon 513		Elevon Top 521				Body Side Top 380
2100.0	2166.0	1115		Body Flap 132	Elevon Bot 424		Elevon Top 425				Body Flap Top 134
Vertical	Tail	1239	Tail 174								Tail 1065
Base		1998									Base 1998
Sub-Total Page 4											
Body Flap				301							
Wing L.E					51						
Elevon – Bottom					939						
Elevon – Top							946				
Body Flap											134
Body Side - Top											380
Base											1998
Vertical Tail			174								1065
Page 4	Total	5986	174	301	988	0	946	0	0	0	3577
Page 3	Total	11508	0	4183	370	389	2196	36	0	1024	3310
Page 2	Total	3851	0	499	872	0	0	248	264	317	1651
Page 1	Total	2051	70	0	827	0	0	611	482	0	61
Vehicle	Total	23396	244	4983	3057	389	3142	895	746	1341	8599

FIGURE 2.4-7 PAGE 1 OF 3

TPS MATERIALS ZONES

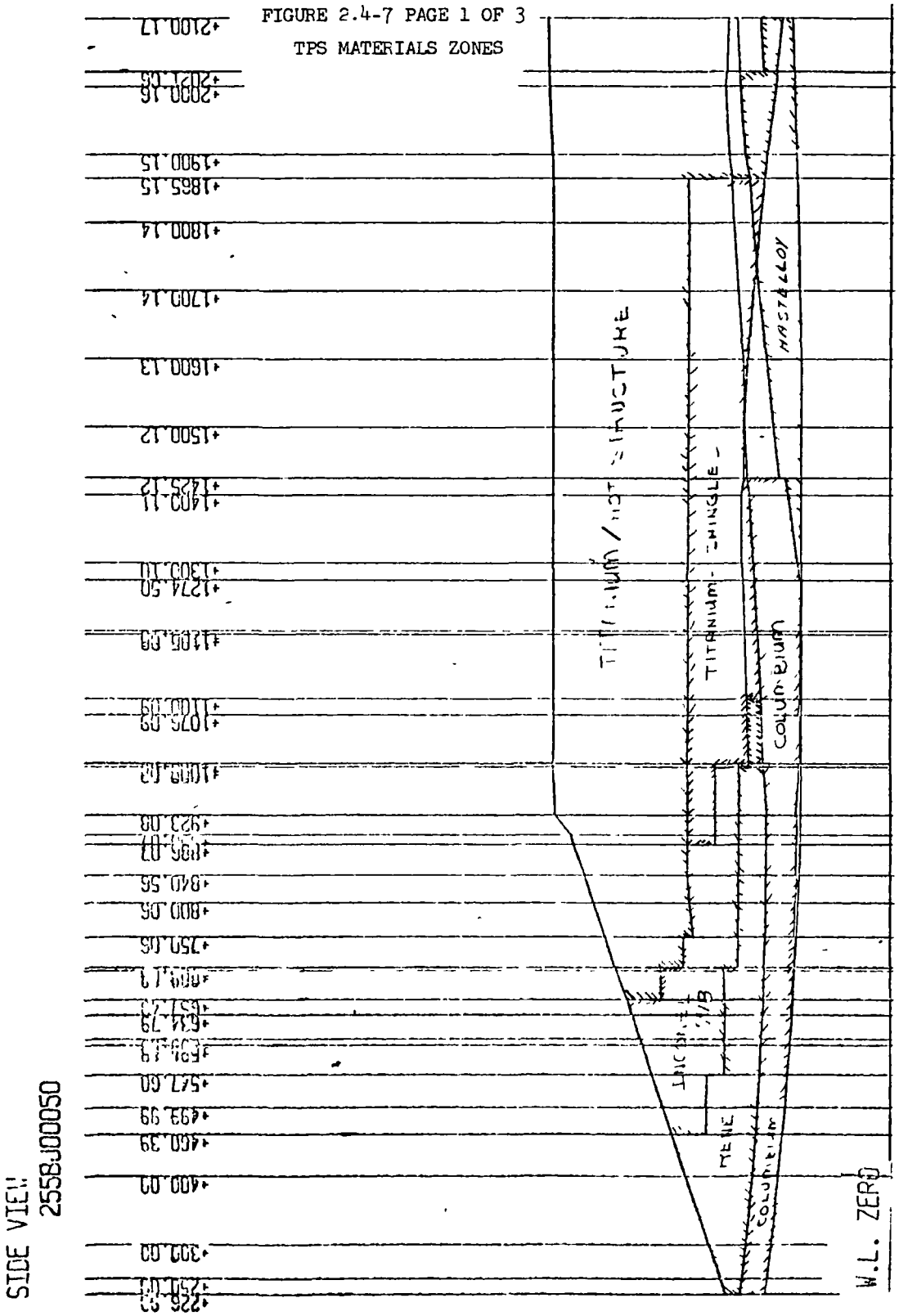


FIGURE 2.4-7 PAGE 2 OF 3

TPS MATERIALS ZONES

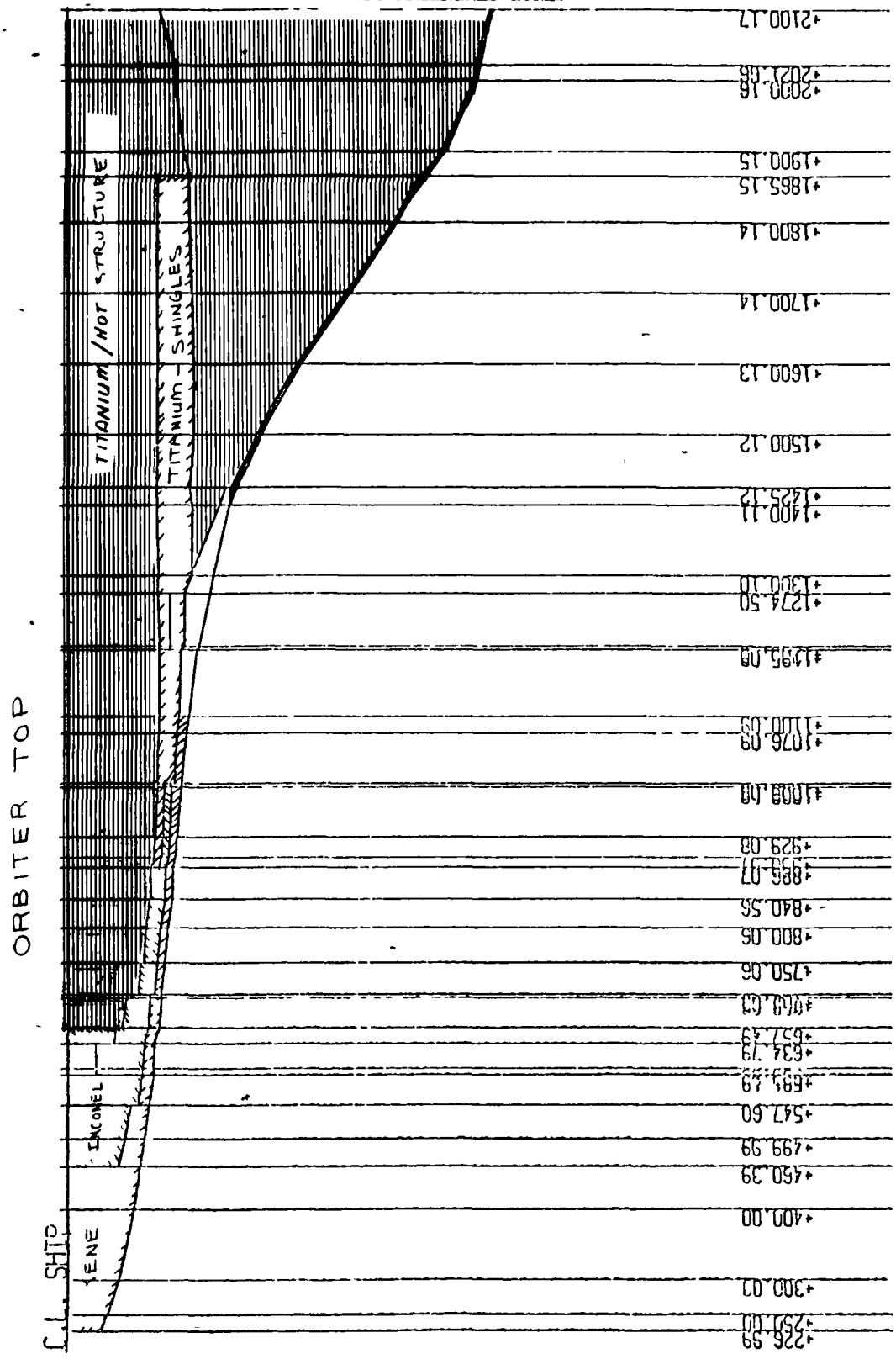
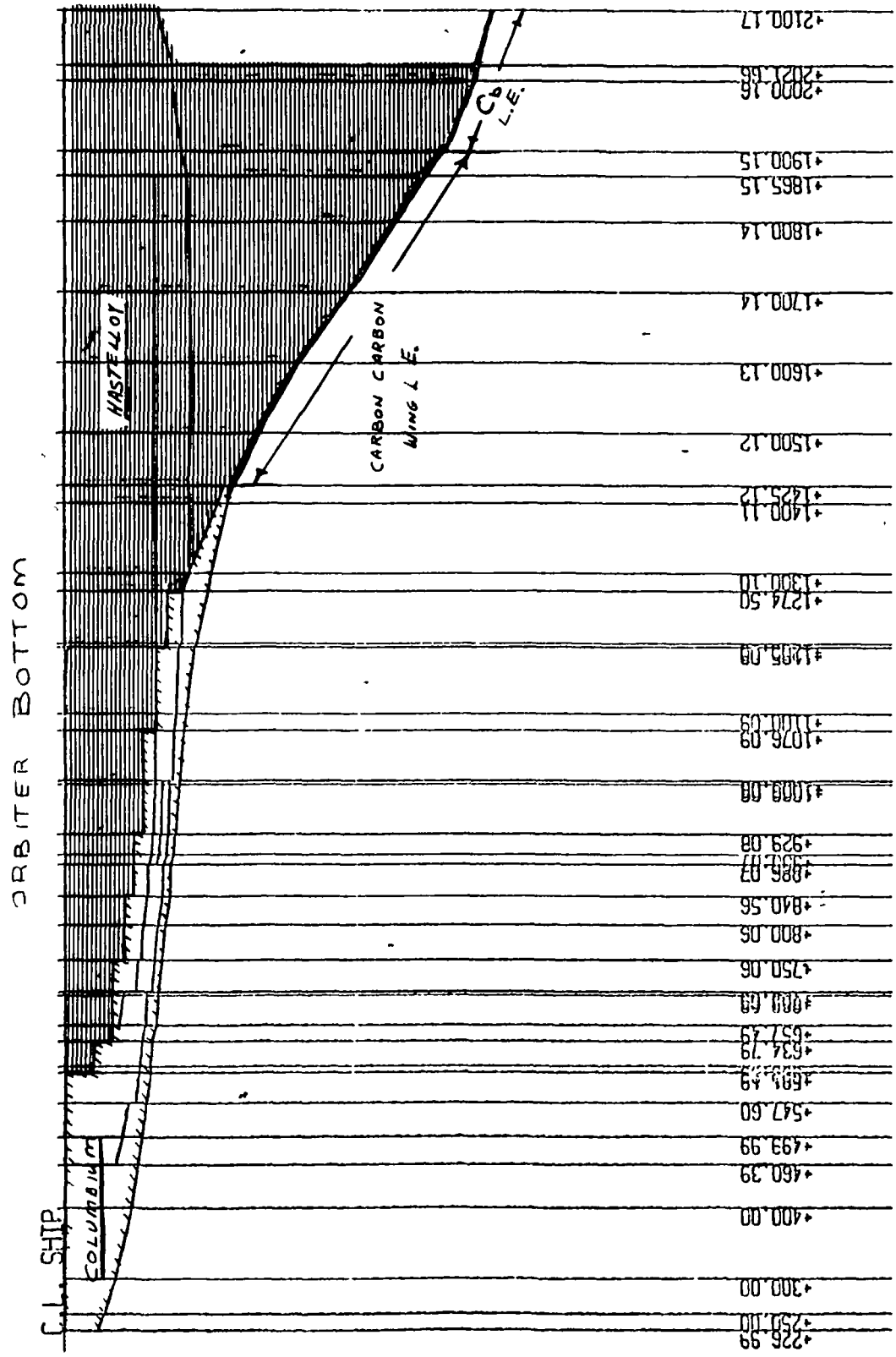


FIGURE 2.4-7 PAGE 3 OF 3

TPS MATERIALS ZONES



The base area calculation resulted in the following:

Item		Area Ft^2
Base Closure Total		1000
Base	216	
Cylinder-Main Engine	673	
Cylinder-RLIO	78	
Cylinder-Thruster	33	
Engine TPS		
Gimbal and Nozzel	478	
Tip of Nozzel	520	

The unit weights determination for leading edge shingle and insulation are presented in Reference 2. The detail breakdown at these data is shown in the following and includes shingle and adjusted insulation density. The insulation density adjustment compensates for the insulation being mounted on the leading edge spar for carbon carbon and two inches inside the mold line for columbium.

ITEM	Body/Nose Cap Carbon-Carbon (PSF)	Wing C-C (PSF)	Wing Cb (PSF)	Tail Cb (PSF)
Carbon-Carbon	3.90	1.96	-	2.28
Columbium	-	-	2.18	-
Spar Delta	-	-	-	.25
Attachments	.39	1.35	.67	.58
Insulation	.71	.90	1.10	1.09
Ins.True Density	(1.70)	(1.70)	(1.27)	(3.78)
Insulation Temp	(2500°/600°)	(2500°/600°)	(2200°/600°)	(300°/1000°)
Total Wetted Area	5.00	4.21	3.95	4.20

The Induced Environment Protection Mass Properties Summary Data is presented in Table 2.4-7.

TABLE 2.4-7

SEQUENCED MASS PROPERTIES SUMMARY

INDUCED ENVIRONMENT PROTECTION

ANALYSIS VEHICLE

DESCRIPTION	CURRENT WEIGHT (LB)	CENTER OF GRAVITY X (INCH)	Y (INCH)	Z (INCH)	MOMENT OF INERTIA ROLL	PITCH	YAW
					PRODUCT OF INERTIA ROL-PIT	PIT-YAW	YAW-ROL
					(SLUG-FEET SQ./1000.)		
NOSE CAP	350.	210.	0.	215.	0.	0.	0.
					0.	0.	0.
BODY BTM	13174.	1041.	0.	151.	23.	747.	828.
					0.	0.	-22.
SIDE&TOP	5369.	996.	-0.	288.	46.	253.	273.
					-0.	-0.	8.
BODY	18543.	1028.	-0.	190.	84.	1018.	1102.
					-0.	-0.	-14.
WING BTM	5398.	1772.	0.	150.	140.	55.	197.
					0.	0.	-0.
ELEVON	2932.	2094.	0.	183.	111.	1.	113.
					0.	0.	0.
BODY FLAP	752.	2086.	0.	146.	1.	0.	2.
					0.	0.	0.
SURF PROTECT	27625.	1315.	-0.	181.	330.	2130.	2469.
					-0.	-0.	-50.
BASE	1886.	2112.	0.	333.	5.	5.	2.
					0.	0.	0.
TPS	29861.	1353.	-0.	191.	353.	2486.	2813.
					-0.	-0.	-6.
CONTINGENCY	2986.	1353.	0.	191.	35.	249.	282.
					0.	0.	0.
INDUCED ENVI	32847.	1353.	-0.	191.	388.	2734.	3095.
					-0.	-0.	-6.

TABLE 2.5-1

DETAIL WEIGHT STATEMENT

	Weight-lbs	Page
2.5 Landing, Recovery, Docking	10551	
Alighting Gear	(7600)	2.5-2
Main Right Hand	3312	
Main Left Hand	3312	
Nose	976	
Docking	(400)	2.5-11
Auxiliary System	(1763)	2.5-18
Deceleration Chutes	258	2.5-18
Interstage Attach	627	2.5-23
Payload Handling	505	2.5-30
Tunnel	373	2.5-35
Contingency	(788)	2.5-36
Alighting Gear	380	
Docking	40	
Deceleration Chutes	13	
Interstage Attach	176	
Payload Handling	142	
Tunnel	37	

2.5 Landing, Recovery, Docking - The Landing, Recovery, Docking weights, presented in Table 2.5-1, were determined in part by statistical correlation (alightment gear and drogue chute)and the remaining by detail evaluation of preliminary design drawings. This section includes Alighting Gear, Docking and the Auxiliary Systems which includes Deceleration Chutes, Payload Handling, Interstage, and Tunnel.

Alighting Gear - The alighting gear estimated weights are primarily based upon the method presented in McDonnell Aircraft Company, Weight Estimation Handbook, Volume 1, Report No. 747, dated 1 January 1971. These methods were developed from data on aircraft of MCAIR and other manufacturers. The equations were developed on the premise that weight is a function of the parameters which describe the physical characteristics of a particular component. These physical characteristics in their simplest form are the physical dimensions and the material density. However, the physical dimensions are the result of a intricate function involving applied loads, structural configurations, material working stresses, environment of the material, design practices, manufacturing technique, etc. Relationships were developed for each increment from the applicable parameters affecting the particular increment. The equations resulting from this formulation are theoretical descriptions of the increment weights, which do not include such intangibles as design practices, material tolerance, manufacturing, etc. This deficiency was overcome by correlating the results of the formulations to the actual weights of each increment. The result then is an equation which contains the theorized relationship of the design influencing parameters adjusted statistically to match the actual increment weights. The MCAIR alignment gear data from Report No. 747, is presented on pages 2.5-44 through 2.5-55.

The MCAIR summary data for landing gear (alighting gear group) are presented in Figure 2.5-1 and Table 2.5-2. These data include eleven (11) McDonnell designs and nineteen (19) designs of other manufacturers. The items of the Shuttle Landing Docking group which have their weight estimated from these data are listed in the following. The weight of the brakes, included in the following, are based upon different data. This is due to the unique design requirements of shuttle brakes and the use of carbon in lieu of steel.

ALIGHTING GEAR		7,600 Lbs
Main Landing Gear	(6,624)	
Structure	2,660	
Running Gear	3,121	
Controls	843	
Nose Gear	(976)	
Structure	563	
Running Gear	176	
Controls	237	

The validity of McAIR weight equation for the load and geometry region of the Shuttle is presented in data on pages 2.5-39 through 2.5-43.

FIGURE 2.5-1 ALIGHTING GEAR GROUP ACTUAL VS ESTIMATED

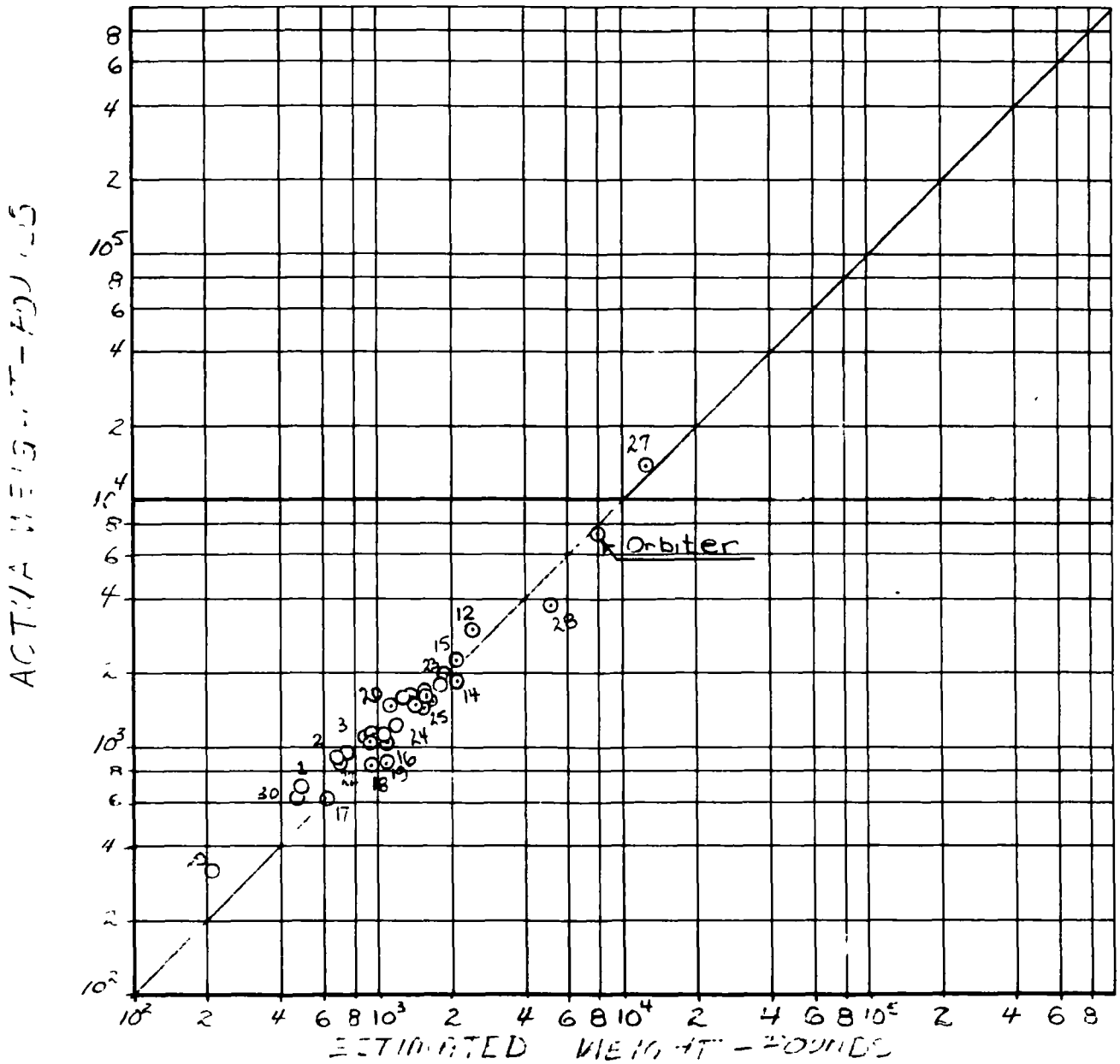


TABLE 2.5-1

ALIGHTING GEAR GROUP

ACCURACY STATISTICS

INDUSTRY WIDE SAMPLE

ALIGHTING GEAR

N	MODEL	WT(ACT)	WT(EST)	WT(EST)-WT(ACT)	X	X-XR	(X-XR)**2
1	[illegible]	668.00	500.10	-167.90	-0.2513	-0.2254	0.0509
2	[illegible]	855.00	717.01	-137.99	-0.1614	-0.1357	0.0184
3	[illegible]	1010.00	848.21	-161.79	-0.1602	-0.1345	0.0181
4	[illegible]	1111.00	1050.89	-60.11	-0.0541	-0.0284	0.0008
5	[illegible]	1413.00	1486.71	73.71	0.0522	0.0779	0.0061
6	[illegible]	1373.00	1515.17	142.17	0.1035	0.1292	0.0167
7	[illegible]	1365.00	1550.09	185.09	0.1356	0.1613	0.0260
8	[illegible]	1737.00	1844.35	106.35	0.0774	0.1033	0.0107
9	[illegible]	1037.00	885.24	-151.76	-0.1463	-0.1206	0.0145
10	[illegible]	1545.00	1601.14	56.15	0.0363	0.0621	0.0039
11	[illegible]	1588.00	1628.32	40.32	0.0254	0.0511	0.0026
12	[illegible]	2814.00	2454.24	-459.76	-0.1634	-0.1319	0.0174
13	[illegible]	815.00	745.31	-69.69	-0.0855	-0.0598	0.0036
14	[illegible]	1973.00	2054.15	81.15	0.0411	0.0669	0.0045
15	[illegible]	2743.00	2585.53	-157.47	-0.0737	-0.0445	0.0020
16	[illegible]	1067.00	1174.92	127.82	0.1221	0.1478	0.0218
17	[illegible]	411.00	412.77	1.77	0.0029	0.0286	0.0008
18	[illegible]	822.00	936.42	114.42	0.1392	0.1649	0.0272
19	[illegible]	873.00	1037.11	164.11	0.1880	0.2137	0.0457
20	[illegible]	1437.00	1173.98	-263.01	-0.1830	-0.1573	0.0247
21	[illegible]	1054.00	934.04	-121.96	-0.1156	-0.0898	0.0081
22	[illegible]	866.00	704.41	-161.59	-0.1866	-0.1609	0.0259
23	[illegible]	1995.00	2003.26	8.26	0.0041	0.0299	0.0009
24	[illegible]	1252.00	1288.42	36.42	0.0291	0.0548	0.0030
25	[illegible]	1396.00	1562.97	168.97	0.1210	0.1326	0.0176
26	[illegible]	1469.80	1606.76	136.96	0.0932	0.1189	0.0141
27	[illegible]	13522.00	12301.17	-1220.83	-0.0903	-0.0646	0.0042
28	[illegible]	3856.00	5117.63	1261.63	0.3272	0.3529	0.1245
29	[illegible]	326.00	207.26	-118.74	-0.3642	-0.3385	0.1146
30	[illegible]	621.00	479.25	-141.75	-0.2283	-0.2041	0.0417

DEGREES OF FREEDOM ARE 29. PROBABILITY OF 95.0
CHI SQUARE VALUE IS 17.70 STUDENT'S T VALUE IS 2.04
SAMPLE MEAN IS -0.0257 STANDARD ERROR IS 0.1521

PROBABILITY-TOLERANCE-INTERVAL

-32.346 PERCENT IS LESS THAN X(I) IS LESS THAN 17.220 PERCENT

PROBABILITY-CONFIDENCE-INTERVAL

-33.401 PERCENT IS LESS THAN X(I) IS LESS THAN 28.455 PERCENT

ALIGHTING GEAR CALCULATION - The equations from MCAIR data presented in pages 2.5-44 2.5-55 are applied to the current Shuttle Orbiter. Thus the current Orbiter characteristics and requirements are utilized to estimate alighting gear weight.

Structure

Main Gear

$G(1) = G(S) + G(BB) + G(A) + G(F)$

$G(S) =$ STRUTS

$= 445\left[\left(\frac{1343}{12}\right) + (.3)(0)\right]^{.95}\left[\frac{118}{11P+65}\right]^{.68} x$

$\left[(1011)(33489)\right]^{.6}(1.0)(2.0)$

$= \underline{2130.84 \text{ lbs}}$

$G(BB) =$ Bogey Beams - Not Applicable

$G(A) =$ Axles

$= 1.425\left(\frac{16.2}{12}\right)^{1.4}(33489)^{.7}(2) = \underline{254.23 \text{ lb}}$

$G(F) =$ Attach Fittings

$= (.06)(2130.84) = \underline{275.14 \text{ lb}}$

$G(1) = 2130.84 + 254.23 + 275.14$

$G(1) = \underline{2660 \text{ lb}}$

Nose Gear

$G(4) = G(NS) + G(NF) + G(A)$

$G(NS) =$ STRUTS

$= 8.64\left[\left(\frac{135.5}{12}\right) + .3(0)\right]^{.91}\left[\frac{105}{105+57}\right]^{.68} x$

$\left[(1.011)(1067)\right]^{.6}(1.)(1.)$

$= \underline{479.80\ lb}$

$G(NF) =$ Attach Fittings

$= (.06)(479.80)^{1.1} = \underline{53.37\ Lb}$

$G(A) =$ Axles

$= 1.425\left(\frac{10.2}{12}\right)^{1.4}(1067)^{.7}(1) = \underline{29.87\ Lb}$

$G(4) = 479\,80 + 53.37 + 29\,87$

$G(4) = \underline{\underline{563\ lb}}$

Running Gear

Main Gear

$G(2) = G(W) + G(B) + G(T) + G(Air) + G(AS)$

$G(W) =$ Wheels

$= 5.02\left(\frac{3344.89}{4}\right)^{.59}\left(\frac{25}{12}\right)^{.7}\left(\frac{17.75}{12}\right)^{.04}(4)$

$= \underline{726.61\ lb}$

$G(B) =$ Brakes

The following equation is applicable for brakes made of carbon and a useful life of five(5) normal landings.

$$G(B) = \frac{1}{2g}(W_L)(1.678\,V_{TD})^2/315{,}000$$

Where

W_L = Landing gross weight, lb

V_{TD} = Touchdown Speed, Knots

g = gravitational acceleration

$$G(B) = \frac{(266488)(1.6878\times 180)^2}{(2)(32.174)(315{,}000)} = \underline{1213.44\ Lb}$$

$G(T)$ = Tires

= 263.2* Lb/each × 4 = 1052.8 Lb

*Vendor data see page 2.5-8

$G(Air)$ = Air

The following simplified Volume, pressure, density equation evaluates the weight of Nitrogen in the TIRES

$$= \frac{2\pi}{1728}\left(\frac{WTM}{2}\right)^2\left(\frac{DWM+WTM}{2}\right)\left(\frac{.07274\times P\times NWM}{15}\right)$$

Where P = Tire Inflation Pressure psi

$$= \frac{2\pi}{1728}\left(\frac{16.2}{2}\right)^2\left(\frac{25+16.2}{2}\right)\left(\frac{.07274\times 260\times 4}{15}\right)$$

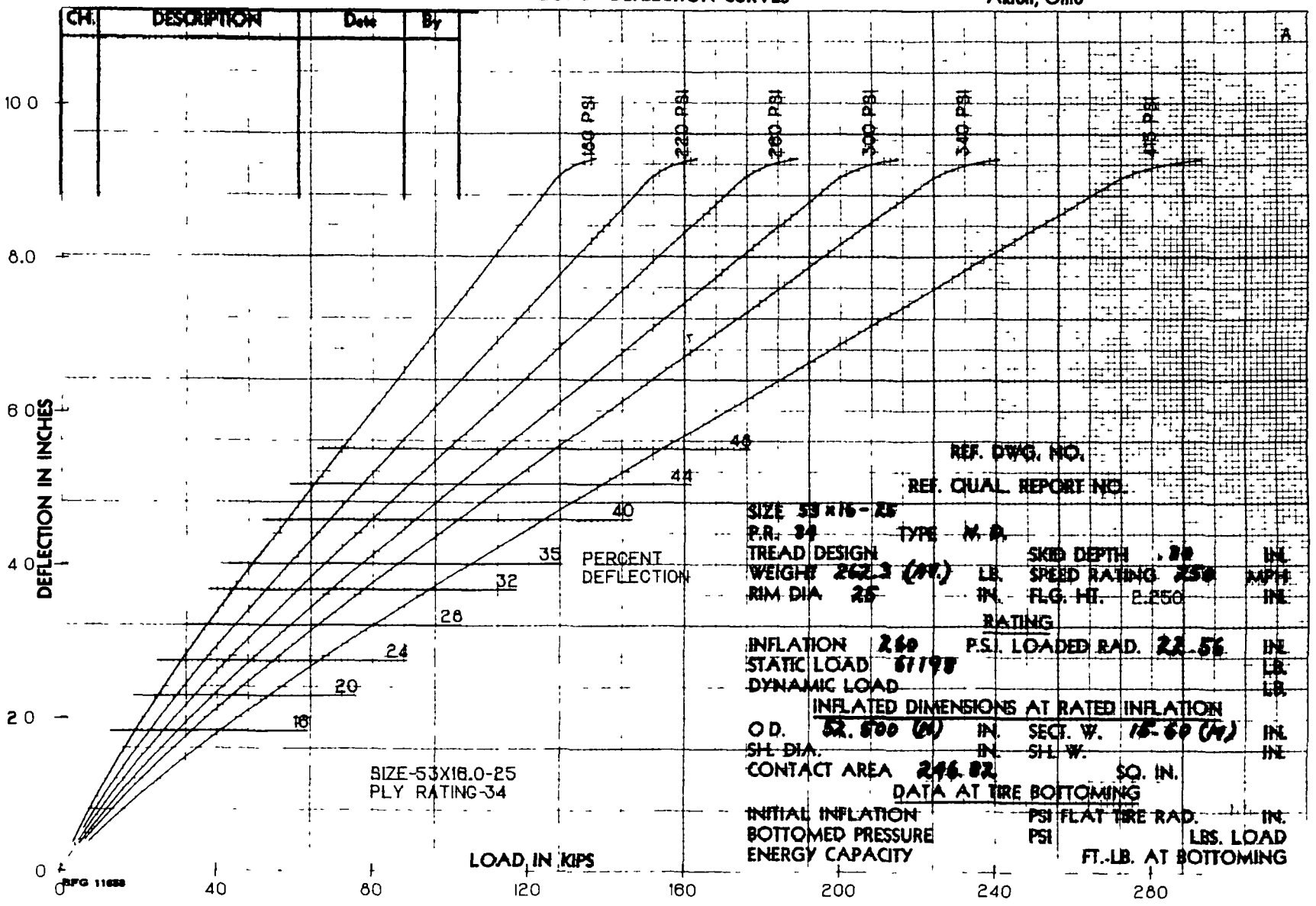
= 77.86 Lb

$G(AS)$ = Anti Skid Device

= 50 lb estimated

$G(2)$ = 726.61 + 1213.44 + 1052.80 + 77.86 + 50.

= 3121 Lb


LOAD - DEFLECTION CURVES
THE B F GOODRICH COMPANY
Akron, Ohio
CH. DESCRIPTION Date By
A
DEFLECTION IN INCHES
LOAD IN KIPS
PERCENT DEFLECTION
48
44
40
35
32
28
24
20
16
140 PSI
220 PSI
260 PSI
300 PSI
340 PSI
380 PSI
SIZE-53X16.0-25
PLY RATING-34
REF. DWG. NO.
REF. QUAL. REPORT NO.
SIZE 53 x 16 - 25
P.R. 34 TYPE M. P.
TREAD DESIGN SKID DEPTH .39 IN.
WEIGHT 262.3 (M.) LB. SPEED RATING 250 MPH
RIM DIA. 25 IN. FLG. HT. 2.250 IN.
RATING
INFLATION 260 P.S.I. LOADED RAD. 22.56 IN.
STATIC LOAD 61198 LB.
DYNAMIC LOAD LB.
INFLATED DIMENSIONS AT RATED INFLATION
O.D. 52.800 (M.) IN. SECT. W. 15.60 (M.) IN.
SH. DIA. IN. SH. W. IN.
CONTACT AREA 246.82 SQ. IN.
DATA AT TIRE BOTTOMING
INITIAL INFLATION PSI FLAT TIRE RAD. IN.
BOTTOMED PRESSURE PSI LBS. LOAD
ENERGY CAPACITY FT.-LB. AT BOTTOMING
RFG 11658

Running Gear

Nose Gear

$G(5) = G(NW) + G(NT) + G(Air)$

$G(NW)$ = Wheels

$= 9.21 \left(\frac{106.7}{2}\right)^{.33} \left(\frac{16}{12}\right)^{.7} \left(\frac{8}{12}\right)^{.94} (2)$

$= 57.00$ lb

$G(NT)$ = Tires

$= 56^{*}$ Lb./each $\times 2 = 112$ Lb

* Vendor Catalogue Data

$G(Air)$ = Air

$= \frac{2\pi}{1728} \left(\frac{10.2}{2}\right)^2 \left(\frac{10.2+16}{2}\right) \left(.072 \times \frac{1754 \times 2}{15}\right)$

$= 6.61$ Lb

$G(5) = 57.00 + 112. + 6.61$

$= 116$ Lb

Controls

Main Gear

$G(3) =$ Controls

$= .225 [2660 + 3121]^{.75}$

$= 84349$ Lb

Nose Gear

$G(6) =$ Controls

$= 1.2 [563 + 176]^{.80}$

$= 236.55$ Lb

ALIGHTING GEAR

7600 Lb

	Main (6624)	Nose (976)
Structure	2660	563
Running Gear	3121	176
Controls	843	237

Docking - The docking system is androgynous and has docking capability with either both sides of docking interface active or only one side active. The active functions are performed from the adapter side of the interface and the system allows rotation orientated docking at 90 degree intervals. The docking system consists of:

Structure

- o Docking Adapter
- o Docking Ring with four (4) Integral Capture Latches

Shock Absorber - Actuator System

- o Shock Absorber/Actuators (eight) - these are mounted between the adapter and ring and are capable of extending and retracting the docking ring. The extend and retract chambers are operated with nitrogen with the damping chamber operating on hydraulic fluids.

Latching and Sealing

- o Rigidizing Latches (twelve) operated to latch prior to seal inflation
- o Rigidizing Latch Actuators (two) each having three (3) electric motors, gearbox, screwjack, and operating six (6) latches on the runaround drive mechanism
- o Latch Release Actuators (four) each has three electric motors, gearbox, screwjack, and compressible piston to allow depression during capture sequence.
- o Alignment Guides (four male/four female) that function during the last 2.5 inches of the retraction stroke
- o Inflatable seal to seal docking interface plane after rigidizing.

Docking System Calculation -

181 Lb

Structure

Adapter

Area

CYLINDER

$(\pi)(D)(H)/144$

$(\pi)(84")(11')/144 = 16\ Ft^2$

BULKHEAD

$(\pi)(R^2-r^2)/144$

$(\pi)(42^2-30^2)/144 = 19\ Ft^2$

$Area = 16+19 = 35 Ft^2$

Unit Weight of Agena Docking Adapter Structure (Reference Gemini Program)

$= 4.0\ PSF$

$Weight = (40)(35) = \underline{140\ Lb}$

Docking Ring

Area – Cone

$\pi(R+r)(H_{SLANT})/144$

$\pi(39+30)(13')/144 = 20 Ft^2$

Docking Ring Area = 50% of Cone $= 10 Ft^2$

Unit Weight of Agena Docking Cone $= 4.1 PSF$

$Weight = (4.1)(10) = \underline{41\ Lb}$

Shock Absorber - Actuators System

Shock Absorber - Actuators

Outer Cyl
Tube
$(.7854)(2.1^2 - 2.0^2)(19.1) = 6.15\ IN^3$

Base End
$(.7854)(2.4^2 - 1.7^2)(0.9) = 2.03\ IN^3$

Top End
$(.7854)(2.1^2)(0.9) = 3.12\ IN^3$

Vol Outer Cylinder
$6.15 + 2.03 + 3.12 = \underline{11.3\ IN^3}$

Mid. Cyl
TUBE $(.7854)(1.7^2 - 1.5^2)(18.6) = 9.36\ IN^3$

ENDS (2) (est) $4.54\ IN^3$

Vol Mid Cylinder
$9.36 + 4.54$ $\underline{13.9\ IN^3}$

INNER CYL

TUBE $(.7854)(4^2 - .2^2)(20) = 1.89\ IN^3$

Weight = (Volume)(Density)(Non-Optimum)

$= (11.3 + 13.9 + 1.9)(.1)(1.20) = \underline{3.25\ LB}$

Eight Shock Absorbers - Actuators

$8 @ 3.25 = \underline{26\ LB}$

Extend - Retract Valves - Eight (8)

Unit Weight 2.25 Lb - TYPICAL FOR 2-WAY SOLENOID ACTIVATED VALVE

2.25 @ 8 = 18 Lb

Hydraulic Fluid in Shock Absorber - Actuator

Bore 1.70 IN Dia. 1.4 IN Dia

STROKE 20 IN

Volume = $(.7854)(1.70^2 - .4^2)(20)$

= $43\ IN^3$

Wt = $(43\ IN^3)(.03\ \#/IN^3)$ 1.25 Lb/ea

Wt for Eight Actuators

Wt = 1.25 @ 8 = 10 Lb

Plumbing (Estimate) 10.0 Lb

Vent Valves - Three (3)

Unit Weight 2.0 lb - TYPICAL FOR 1-WAY SOLENOID ACTIVATED VALVE

2.0 @ 3 6.0 Lb

Circuitry (Estimate) 10.0 Lb

Mountings (ESTIMATE) 10.0 Lb

Pressurant Systems – Three

SYSTEM NO 1		12 Lb
NITROGEN	1 Lb	
TANK (NASA GEMINI RCS)	2 Lb	
VALVING	8 Lb	
ON-OFF SOLENOID	2 Lb	
Regulator	5 Lb	
Check Valve & Plumbing	1 Lb	
MOUNTING	1 Lb	
SYSTEM NO 2		12 Lb
SYSTEM NO 3		12 Lb
Total Three Systems		(36 Lb)

Summary
Shock Absorber – Actuator System

Shock Absorber - Actuators (8)	26 Lb
EXTEND RETRACT VALVES (8)	18 Lb
HYDRAULIC FLUID – Shock Abs (8)	10 Lb
PLUMBING	10 Lb
VENT VALVES – (3)	6 Lb
CIRCUITRY	10 Lb
PRESSURANT SYSTEM	36 Lb
MOUNTING	10 Lb
Total	126 Lb

Latching and Sealing

Rigidizing Latches - Twelve — 12Lb

Estimated Unit Weight - 1 Lb

Rigidizing Latches - Actuator - Two — 20Lb

Estimated Unit Weight 10Lb

Breakdown

Motor 1.5Lb ea	4.5
Gear Box	= 2.0
Screw JACK	- 1.5
Mounting Etc.	- 2.0

Drive System — 18Lb

Estimated Unit Weight 0.8 Lb/Foot

Wt = (π)(84")/12 @ .8 Lb/Foot

CAPTURE LATCHES AND ACTUATORS - FOUR (4) — 8Lb

Estimated Unit Weight 2.0Lb/ea

ALIGNMENT GUIDES - FOUR MALE & FEMALE — 2Lb

Estimated Unit Weight 0.5Lb/set

Inflatable Seal — 10Lb

Estimated Weight - 10Lb

TOTAL — 70Lb

CONTROLS (ESTIMATE) — 23Lb

Docking System Summary 400 Lb

STRUCTURE	181 Lb
Shock Absorber Actuator System	126 Lb
Latching and Sealing	70 Lb
Controls	23

AUXILIARY SYSTEMS 1,763 Lbs

The auxiliary systems includes the Deceleration Chutes, Interstage attach, Payload Handling, and Tunnel System. The weight estimates for the Deceleration Chutes have been established by applying McDonnell Astronautics methods for determining subsonic parachute weights. The development of these equations followed an approach similar to MCAIR alighting gear data. Hardware correlation has been used to determine equations for subsonic parachute canopy and risers. Other components are percentage of canopy weight. The following expression has been found to agree with existing data for ring sail and conical ribbon canopies, as shown in Figure 2.4-2.

$$W_p = .0074\ (q\ C_D)^{.57}\ (D_o + 3\ D_o)$$

W_p = Chute Canopy Weight - lb

where q = Chute Pressure - psf

C_D = Chute drag coefficient

C_o = Effective chute diameter

The chute riser weight depend upon the maximum drag force multiplied by a safety factor. This determines the total strength of all the risers. The number of risers or suspension lines for a chute is typically one for each 2.5 feet of circumference. In practical use this is unrealistic as it will indicate that there is a fractional number of suspension lines. The improved expediency and the small amount of weight error, if any, allow the acceptance of this unrealistic number of lines for the purpose of estimating weight.

$$n = \frac{\pi D_o}{2.5} \quad \text{Number of risers}$$

The maximum drag force results from the maximum dynamic pressure times the chute area and coefficient of drag. The safety factor of 2.3 is used to determine the total breaking strength of all risers. Dividing by number of risers results in the required breaking strength of a riser.

S = breaking strength of a riser

$$S = \frac{.7854\ D_o^2\ C_D\ q\ 2.3}{n}$$

The riser unit weights $(W/L)_R$ for a nylon riser material is presented in Figure 2.4-3. The MIL-W-27657 (USAF) nylon riser is assumed for the shuttle.

$$\left(\frac{W}{L}\right)_R = .077\left(\frac{S}{1000}\right)^{.91}$$

The weight of Mercury and Gemini chute containers, and chute attachment are defined by the following equations.

$$\text{Chute Container} = .12\ W_p$$

$$\text{Attachment} = .20\ W_p$$

The circuitry weight including relays etc. was approximately four (4) pounds for the Gemini and Mercury landing chute system. An estimate of 20 pounds of circuitry, 10 for drogue and 10 for pilot, has been provided for the Shuttle.

FIGURE 2.5-2 - PARACHUTE HARDWARE CORRELATION

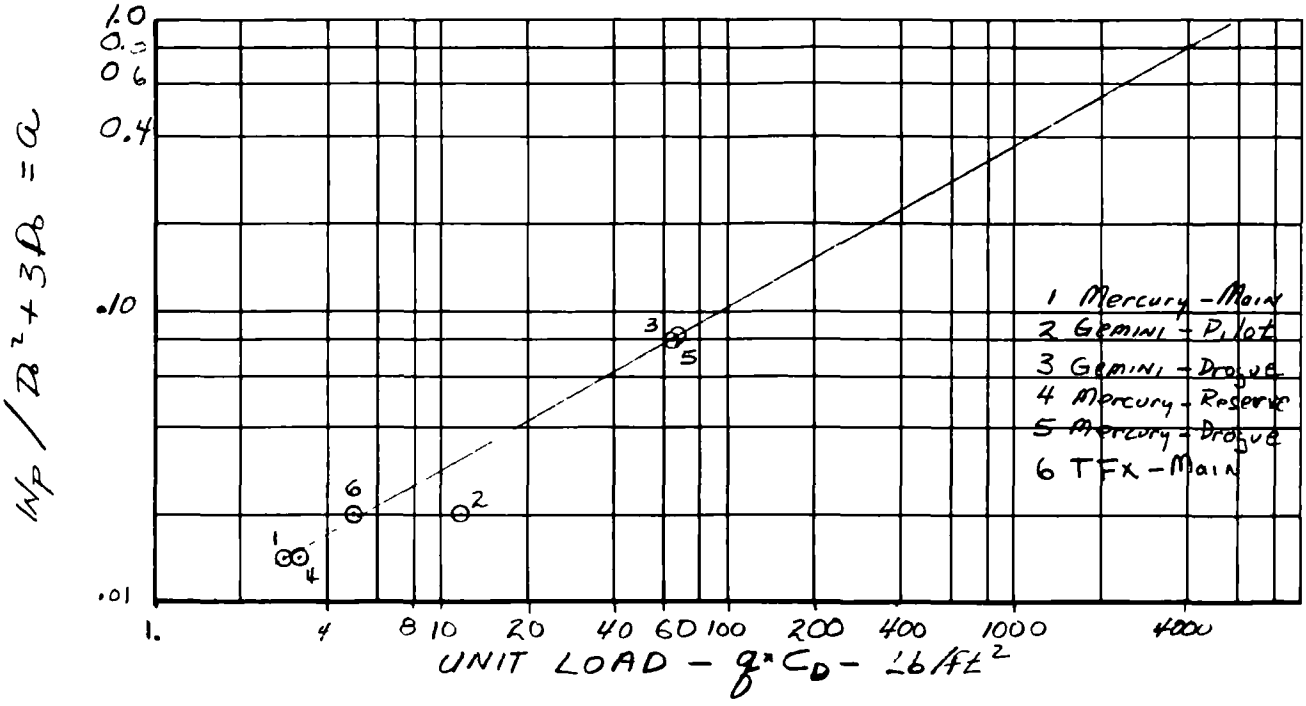
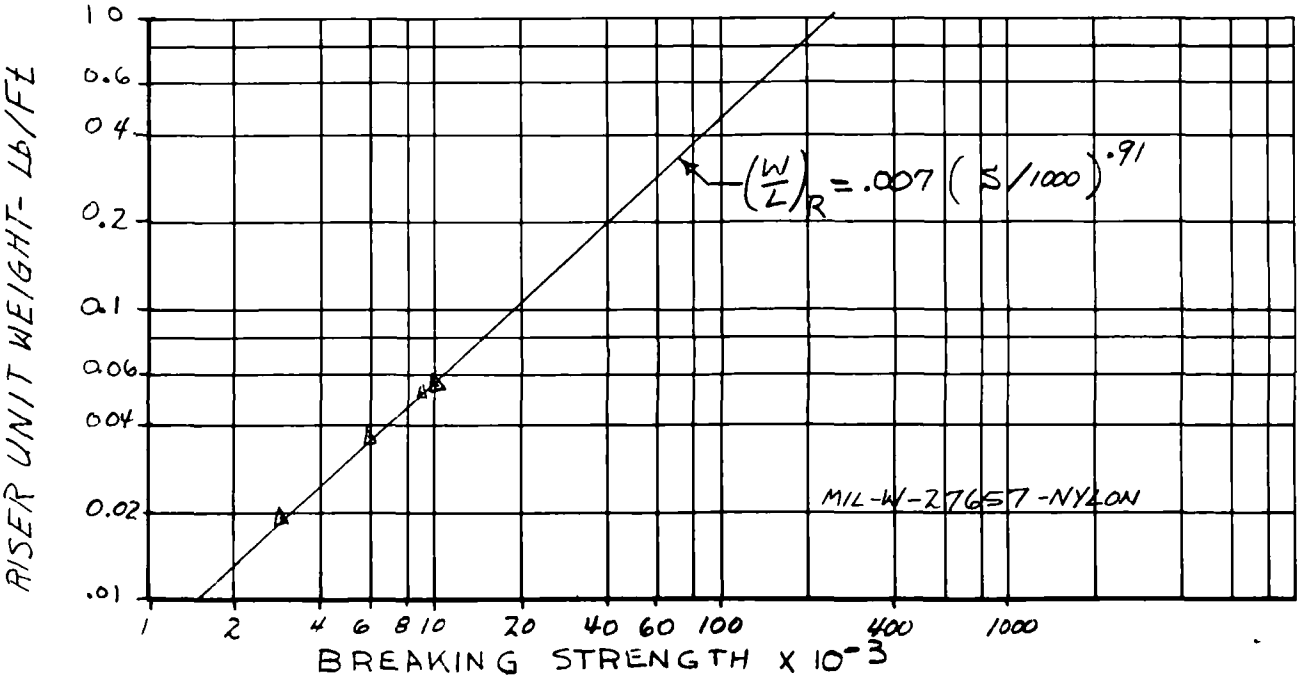


FIGURE 2.5-3 RISER UNIT WEIGHT (LB/FT) VS. BREAKING STRENGTH



$$G(\text{Deceleration Chute}) = G(\text{Drogue}) + G(\text{Pilot})$$

$$G(\text{Drogue}) = G(cp) + G(R) + G(\text{cont}) + G(AH) + G(\text{Line})$$

$$G(cp) = \underline{\text{Canopy}}$$

$$= .0074\left[(Q)(C_D)\right]^{.57}(D_o^2 + 3D_o)$$

where

Q = Chute Pressure

$$= \frac{.07528}{2g}(1.6878\,V_{TD})^2$$

$C_D = .5$, $V_{TD} = 195$ Knots

$D_o = 40$ Ft $\quad Q = 126.6$

$G(cp) = \underline{135.46\ lb}$

$$G(R) = \underline{\text{Risers}}$$

$$= n\ D_o\left(\frac{W}{L}\right)_R$$

Where

n = Number of Risers

$$= \frac{D_o \pi}{2.5} = \frac{(40)(\pi)}{2.5} = 50.27$$

$\left(\frac{W}{L}\right)_R$ = Riser Unit Weight

$$= .007\left(\frac{S}{1000}\right)^{.91}$$

Where

S = Riser Breaking Strength

$$S = \frac{\pi}{4n} C_p (D_o)^2 Q (2.3)$$

$$S = \left(\frac{\pi}{4 \times 50.27}\right)(.5)(40)^2(126.6)(2.3)$$

$S = 3640$

$\frac{W}{L} = (.007)\left(\frac{3640}{1000}\right)^{.91}$

$= .0227$

$G(R) = (50.27)(40)(.0227)$

$= \underline{45\ 64\ Lb}$

$G(CONT)$ – Container

$= .12 \times G(CP)$

$= .12 \times 135\ 46$

$= \underline{16.25\ Lb}$

$G(ATT) =$ Attachment

$= .20 \times G(CP)$

$= .20 \times 135.46$

$= \underline{27\ 09\ Lb}$

$G(Circ) =$ Circuitry

$= \underline{10.0\ Lb}$ (ESTIMATE)

$G(Drogue) = 135.46 + 45\ 64 + 16\ 25 + 27\ 09 + \cdots$

$= \underline{234\ lb}$

$$G(Pilot) = G(CP) + G(R) + G(contl) + G(AH) + G(Circ) + G(EJEC)$$

$$G(CP) = .0074\left((126.6)(.5)\right)^{.57}\left[(7)^2 + (8)(7)\right]$$

$$= \underline{5.5116}$$

$$m = \frac{(9\pi)(7)}{2.5} = 8.8$$

$$S = \left(\frac{9\pi}{4 \times 8.8}\right)(.5)(7)^2(126.6)(2.3)$$

$$S = 636.7$$

$$\left(\frac{W}{L}\right)_R = .007\left(\frac{6367}{1000}\right)^{.91}$$

$$= .0232$$

$$G(R) = (8.8)(7)(.0232)$$

$$= \underline{1.4316}$$

$$G(Contl) = (12)(5.51)$$

$$= .6616$$

$$G(AH) = (.20)(5.51)$$

$$= \underline{1.1016}$$

$$G(EJEC) = \underline{5.016} \quad \text{ESTIMATE}$$

$$G(Circ) = \underline{10.016} \quad \text{ESTIMATE}$$

$$G(Pilot) = 5.51 + 1.43 + .66 + 1.10 + 5. + 10.0$$

$$= \underline{23.716}$$

Deceleration Chutes = 234 + 24 = $\underline{\underline{2581 6}}$

Interstage 627 Lbs

The booster provides a three-point connector/separation system and a static shear post to mechanically mate the orbiter to the booster. The forward structural attach point is a hot gas ram which reacts launch inertia and aerodynamic loads in all directions. The two aft structural links are designed to adapt to misalignments, tolerances and thermal differences between the two vehicles. These links react pitch and roll moments and vertical loads. The shear post reacts side loads and orbiter yaw moments. The orbiter interstage system consists of the bearing plate at the forward attach point, fittings at the two outboard aft attachment points and a shear fitting for the booster shear post at the aft center attachment.

INTERSTAGE WEIGHT CALCULATION -
Forward Attachment and Release 24#6

Bearing Plate - Steel 5#6

Boss (2)

3.3 Inch Diam by 4.4 Inches

Vol $.7854(3.3)^2(4.4) = 38\ IN^3$/ea

Wt = 10 #6/ea

Wt for Two 20#6

Plate Center

Volume $135\ IN^3$

Wt $= (.284)(138) = 39\#6$

Rotation System 24#6

Housing

$\pi(1.725^2 - 1.625^2) \times 6 = 7\ IN^3$

$Wt = (.284)(7) = 2\#6$

Plate

$\pi(1.725)^2(.6) = 5\ IN^3$

$Wt = (.284)(5) = 1.4\#6$

SPRING 1.4#6

Shaft

$(.7854)(.7)^2(10) = 4\ IN^3$

$Wt = (.284)(4) = 1.2\#6$

Closure

$(.7854)(3.7)^2(1.0) = 11\ IN^3$

$WT = (.284)(11) = 3.1\ Lb$

Gear Box (Estimate) 10 lb

Mounting (Estimate) 4.9 lb

THERMAL PROTECTION SYSTEM WEIGHT 44 lb

Area $18'' \times 10'' = 1.25\ FT^2$

$Wt = 1.25\ FT^2 \times 3\ PSF = 3.8\ lb$

BACKUP RELEASE 99 Lb

Actuators	46.7* Lb/ea @ 2	93.4
Mountings (estimate)		5.6

* See Following Page for Single Actuator Analysis per procedure of Section 2.11

Attachment Fittings – Two 40 Lb

Base $6.8 \times 6.8 \times .5 = 23\ IN^3$
Web $5.3 \times 3.0 \times .5 = 8\ IN^3$
Web $5.8 \times 3.0 \times .5 = 9\ IN^3$
Cylinder $.7854(4.8^2 - 3.8^2)(4.1) = 28\ IN^3$

$WT = (.284)(23 + 8 + 9 + 28) = 20\ Lb/ea$

Bushings – Two 10 Lb

Cylinder $(.7854)(3.8^2 - 3.3^2)(4.5) = 13\ IN^3$
Stop $(.7854)(4.6^2 - 3.3^2)(0.4) = 3\ IN^3$
$WT = (.284)(13 + 3) = 5\ Lb/ea$

EM SINGLE ACTUATOR ANALYSIS

BACKUP RELEASE SYS

HINGE MOMENT =	0. IN-LB	SURFACE TRAVEL =	.00 DEG
MOMENT ARM =	.00 IN	SURFACE RATE =	.00 DEG/SEC
STROKE =	4.75 IN	FACTOR OF SAFETY =	1.50
FLOW RATE =	.00 GPM	HORSEPOWER =	.00 HP
OPERATING PRESS =	10000. PSI	BURST PRESSURE =	25000. PSI

DESIGN AXIAL LOAD =	0. LB
OPERATING AXIAL LOAD =	75000. LB
ULTIMATE AXIAL LOAD =	112500. LB

MATERIAL - STEEL		DENSITY = .283 PCI	E = 30000000. PSI
FTU = 280000. PSI		FCY = 240000. PSI	
CYLINDER LENGTH =	13.06 IN	CYLINDER DIAM =	3.63 IN
CYL WALL THICK =	.162 IN	ROD DIAMETER =	1.91 IN
ROD WALL THICK =	.133 IN	END THICKNESS =	.636 IN
PISTON AREA =	7.50 SQ.IN.	PISTON THICK =	.747 IN
SWEPT VOLUME =	35.62 CU.IN.	NON-OPT FACTOR =	1.7426
ROD D/T =	13.90		

POD WEIGHT =	10.91 LB.
PISTON WEIGHT =	1.59 LB.
CYLINDER WEIGHT =	9.85 LB.
NON-OPTIMUM =	16.59 LB.
BASIC ACTUATOR WT =	38.94 LB.
END MNTG WEIGHT =	6.70 LB.
VALVES & CONTROL WT =	.00 LB.
SECONDARY WEIGHT =	.00 LB.
TOTAL ACTUATOR WT =	45.63 LB.
PYRO WEIGHT =	1.07 LB.
TOTAL WET WEIGHT =	46.70 LB.

Attachment 8 lbs

0.5 Lb/ea @ 16 places

Summary – Forward Attachment and Release

Bearing Plate	59 Lb
Rotation System	24 Lb
Thermal Protection Delta	4 Lb
Back-up Release	99 Lb
Attachment Fittings	40 Lb
Bushings	10 Lb
Attachment	8 Lb
Total	244

Aft Attachment and Release – Two 192 Lb

Fittings Two Each @ Two Locations 50 Lb

Volume $14.5 \times 3 \times 1. = 43.5 IN^3$

$Wt = (.284)(43.5) = 12.5$ Lb/ea

Bolts Two Each @ Two Locations 12 Lb

Volume $= (.7854)(1.5)^2(6.0) = 10.8 IN^3$

$Wt = (1.284)(10.8) = 3$ Lb/ea

Pyro Bolt - Two — 4Lb

$Vol = (.7854)(1.125)^2(6) = 6.0$

$Wt. = (1.284)(6.0) = 2\ Lb$

Pyro System (Estimate) — 10Lb

Pyro Circuitry (Estimate) — 10 Lb

Doors and TPS Delta — 30 Lb

Door Penalty 10 Lb/ea

TPS Delta 5 Lb/ea

Attach Fittings - Two — 68Lb

BASE $10 \times 6 \times 1 = 62\ IN^3$

Web $(5 + 10/2) \times 3.8 \times 2 = 59\ IN^3$

$Wt = (.284)(62 + 59) = 34\ Lb$

Attachment Hardware — 8Lb

.5Lb/ea @ 16 places

Summary - Aft Attachment and Release

Fittings (4)	50Lb
Bolts (4)	12 Lb
Pyro Bolts (2)	4 Lb
Pyro System	10 Lb
Pyro Circuitry	10 Lb
Doors and TPS Delta	30Lb
Attach Fittings	68Lb
Attachment Hardware	8 Lb
Total	192Lb

Aft Attachment – Shear Post 191Lb

Fittings 179Lb

Cyl Sections

$Vol_1 = (.7854)(7.2^2 - 5.0^2)(10) = 210.9\ IN^3$

$Vol_2 = (.7854)(7.2^2 - 2.0^2)(1) = 37.6\ IN^3$

$Vol_3 = (.7854)(3.2^2 - 2.0^2)(44) = 20.8\ IN^3$

$Vol_4 = (.7854)(2.0^2 - 1.0^2)(10) = 23.5\ IN^3$

Webs – Two

$30 \times 14 \times .5 = 165\ IN^3 @ 2 = 330\ IN^3$

$k/t = (.284)(211 + 38 + 21 + 24 + 330) = 179Lb$

Springs (Estimate) 2Lb

TPS Delta Wt 2Lb

Attach Hardware 8Lb
.5Lb/ea @ 16 places

Summary Interstage (627Lb)

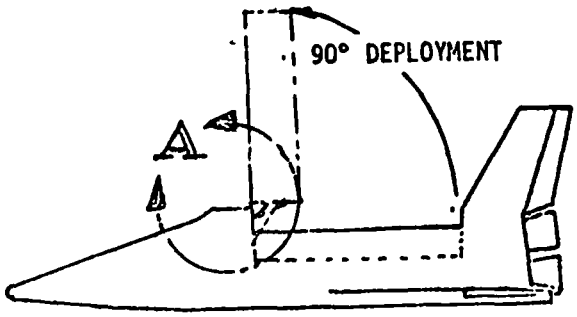
Forward Attachment and Release	244 Lb
Aft Attachment and Release	192 Lb
Aft Attachment – Shear Post	191

Payload Handling 505 Lbs

The payload handling includes the payload structural attachment fittings, and payload deployment systems. The payload support arrangement includes two shear fittings on the ℄ of the bay botton which react side loads and yaw moments. There are also three other payload fittings and payload hold down fittings. The hold down fittings are integral with the payload bay door. The payload attachment also includes two snubbers at the bay bottom. The payload deployment system includes a fram system which interconnects the docking adapter with the orbiter and provides the system for rotational deployment of the payload.

PAYLOAD DEPLOYMENT & DOCKING MECHANISM

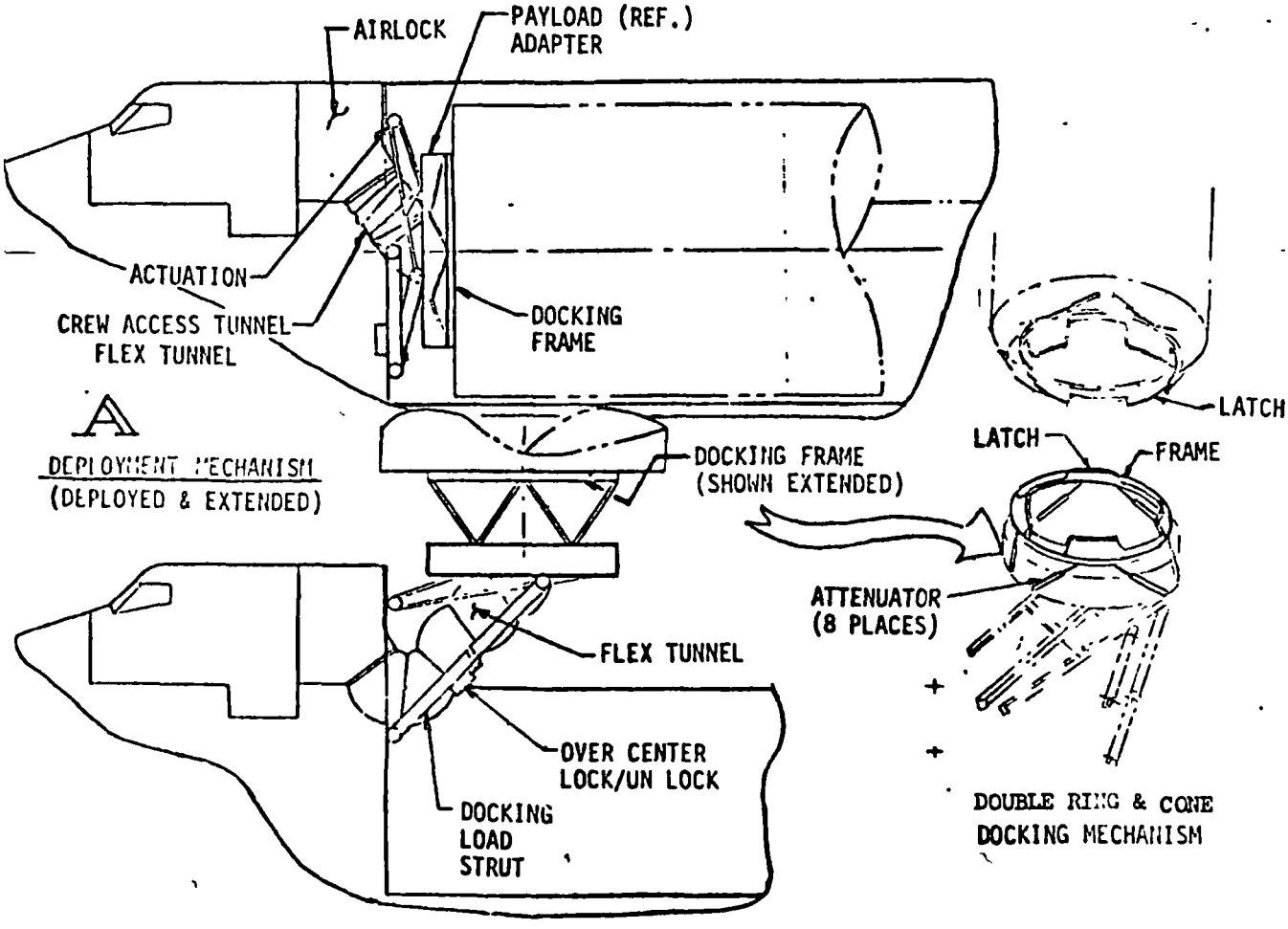
(DELTA WING ORBITER)



- 90° DEPLOYMENT FOR PAYLOAD DOCKING AND RETRIEVAL
- ACTUATOR LOCATED INSIDE AIRLOCK (PRESSURIZED)
- DOCKING MECHANISM - (ANDROGYNOUS) DOUBLE RING & CONE TYPE
- DOCKING MECHANISM TAKES NO FLIGHT LOADS

A

DEPLOYMENT MECHANISM
(Stowed Position)



PAYLOAD HANDLING CALCULATION (5054 Lb)

Deployment Mechanism 3911 Lb

Frame 1571 Lb

Length 872 inches @ 2 = 1744 inch
Web Height ≃ 10 inches
Cap Area = .2 IN²
Web Thickness .080 IN

k/t 1571 Lb

Caps = (.100)(1744)(.2) = 35
Webs = (.100)(872 x 10)(.08) = 70
Joints = 50% @ 105 = 52

Rotation Fittings – Two 201 Lb

Boot 10 x 10 x .5 = 50 IN³
Web (5+10/2) x 3 = 21 IN³
Cyl (785)(4.8²-3.8²)(4.2) = 29

k/t = (.100)(100) = 101 Lb

Brace Fittings – Two 301 Lb

(Estimate) 151 Lb/ea

Motors (Estimate) 301 Lb

Torque Tubes - Two 50Lb

Length 39 Inches

Diam = 2.9 inches

Wt = (.100)(.7854)(2.8)^2(39)

= 25Lb /ea

Gear Drive (ESTIMATE) 30Lb

STRUTS (ESTIMATE) 50Lb

Fittings Strut (ESTIMATE) 24Lb

Summary

Frame	157
Rotation Fittings	20
Brace Fittings	30
Motors	30
Torque Tubes	50
Gear Drive	30
Struts	50
Fittings-Strut	24
Total Deployment Mechanism	391

Payload Support 114lb

Shear Fitting – Two 14Lb

Base $10 \times 6 \times .5 = 30 IN^3$
Receptical est $30 IN^3$
wt = (.100)(30+30) = 6.Lb
Attachment est 1.1b

SUPPORT FITTINGS – THREE 21Lb

BASE $3.0 \times 5.6 \times .5 = 8.4 IN^3$
WEB $5.6 \times 6.8 \times .5 = 19.1 IN^3$
WEB $4.5 \times 2.5 \times .5 = 5.6 IN^3$
WEB $1.8 \times 2.5 \times .5 = 2.3 IN^3$
WEB $1.8 \times 2.5 \times .5 = 2.3 IN^3$
$(37.7 IN^3)$
wt = $(.164)(37.7 IN^3)$ = 6.2 Lb
Attachment (est) 0.8 Lb

HOLD-DOWN FITTINGS – THREE 21Lb
(ESTIMATED SAME AS Support)

SNUBBERS (ESTIMATE) 58Lb

Total 1144lb

Tunnel 373Lb

The crew access tunnel is constructed of reinforced coated fabric. This material and general design criteria is being developed on the current SKYLAB program as a DOD experiment.

The weight estimation has been provided by Goodyear Aerospace Corporation.

Expandable Material 366 Ft^2 @ .54 PSF	198Lb
Terminal Rings 8 rings @ 15.8 lb/each	126 Lb
Fasteners 100 / JOINT @ 5 JOINTS	19 Lb
Shapping Rings 4 tubes @ 5 lb/each	20 lb
Guide Strats 4 @ 2.5 lb/each	10 lb

Contingency - Landing, Recovery and Docking 7884

The Landing, Recovery and Docking system estimated weight data are based upon different pedigree of design information and they represent different complexity of designs. In all cases there are many details of these designs which will be established later in the Shuttle program.

A contingency weight based upon the pedigree of design data and the design complexity is incorporated to account for the effects of these design details. The contingency weights are percentages of the estimated data and vary from five (5) percent for the Alighting Gear and the Deceleration Chute, ten (10) percent fro the Docking Adapter and Transfer Tunnel, to twenty-eight (28) percent for the complex mechanism of the Payload Handling and the Interstage.

The Landing, Recovery and Docking contingency determination is presented in the following.

Item	Basic Weight Lb.	Percent Contingency.	Contingency Weight-Lb
Alighting Gear	7600	5%	380
Docking	400	10%	40
Deceleration Chute	258	5%	13
Inter stage	627	28%	176
Payload Handling	505	28%	142
Tunnel	373	10%	37
Total			788

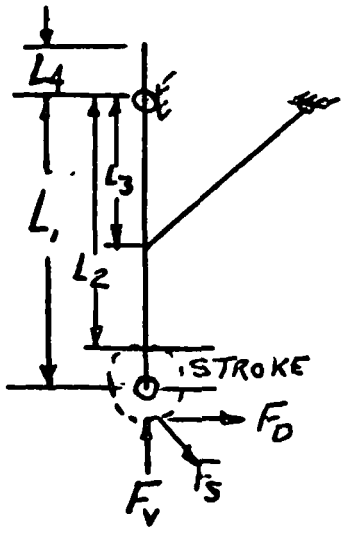
USE OF MCAIR WEIGHT PREDICTIONS FOR SHUTTLE LANDING GEAR

Summary

The McAIR Weight equations for landing gear structure appear valid for the load-geometry region of the Shuttle and should be used. These equations are empirical and based on correlation to some 30 aircraft, mostly fighters and gears under 6 foot long. To examine the validity in the loading range (260,000 to 550,000 lbs weight) and strut length (12 feet to 9 feet) of the Shuttle Orbiter and Booster available date was gathered on all known large aricraft. Correlation was made to DC-8-63, DC-9, DC-10, C-5, BAC747, XB70, and the B-36. These correlations are not conclusive but they suggest the McAIR equation weights are reasonable and more valid than use of a percent of Gross Weight method.

1.0 MCAIR GEAR EQUATION, Derivation and Constreints

The selection of parameters and constraints considers the gear as a simple column:



Boundary Conditions

Pure column $F_{S,D} \longrightarrow 0$

$$Wt = \frac{\rho}{f} F_V L$$

Bending column $F_V \longrightarrow 0$

$$Wt = C_1 L + \frac{\rho}{f} F_V L^2$$

Material not sized by load F_V, $F_{SD} \longrightarrow 0$

$$Wt = C_2 L$$

Material not sized by load or length

$$Wt = C_3$$

$$\sum Wt + C_3 + C_A L + \frac{\rho}{f} F_V L + \frac{\rho}{f} F_V L^2$$

Other correlations on moderately complex structures show a $Wt = f(\text{load, geometry})^{.6}$ relationship thus a gear equation is anticipated to take the form of

$$W_t = \left[C + \frac{\rho}{f} F_V L^{1<m<2}\right]^{\approx .6}$$

The McAIR gear weight equation developed from correlations and the above constraints is:

$$W_{strut} = .42 \left[L^{1.6} F_V \frac{\rho}{f}\right]^{.6} R_B^{.68} k_m N$$

where:

$$L = L_1 + .3L_4$$

$$R_B = 1/(1 + L_3/L_2)$$

k_m = material factor, steel = 1.0 alum = .82

F_V = Vertical reaction, max. ultimate/(strut)(10^3)

30 A/C are correlated with a PTI of about ± 20%

FH-1	F3H-2	F-101C	A-7A	F-102A	S-2E
F2H-1	F4H-1	A3D-2	F-5A	F-104E	B-52H
F2H-2	F4H-	A4D-2N	F-8F	F-105B	B-58A
F2H-3	XF-88	A-5A	F-11F	F-106B	T-37A
F3H-1N	F-101A	A-2E-1	F-100D	C-1A	T-39D

In the correlations, only 2 parameters, gear reaction and length have a significant effect on gear weight. The variation of these parameters for the correlation points was

L 3.26 ft to 7.35 ft.

F_V 13,500 lbs to 36,000 lbs.

2.0 ADDITIONAL CORRELATIONS

Since the correlation points do not bound the Shuttle load/size region, all available data was obtained and correlated on large aircraft.

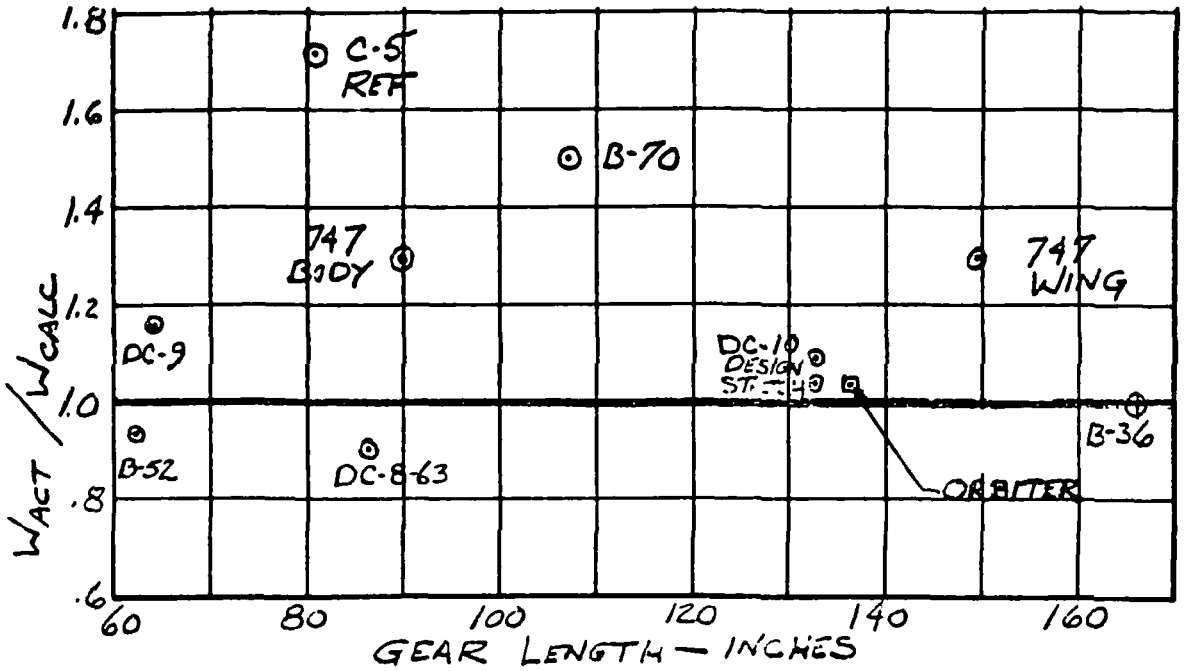
	Landing Weight-lbs	Length Gear-ft
Shuttle Orbiter	270,000	12
Booster	550,000	9
Data Points		
DC-8	355,000	7.3
DC-9	108,000	5.4
DC-10	430,000	11.1
XB-70	542,000	9.0
C-5	769,000	6.7
B-36	410,000	13.9
BAC-747	713,000	7.1 Fus, 12.4 Wing

The McAIR predicted weight accuracy is compared to the two major parameters controlling gear weight, gross weight, and length. A significant scatter of data is seen, however it is noted:

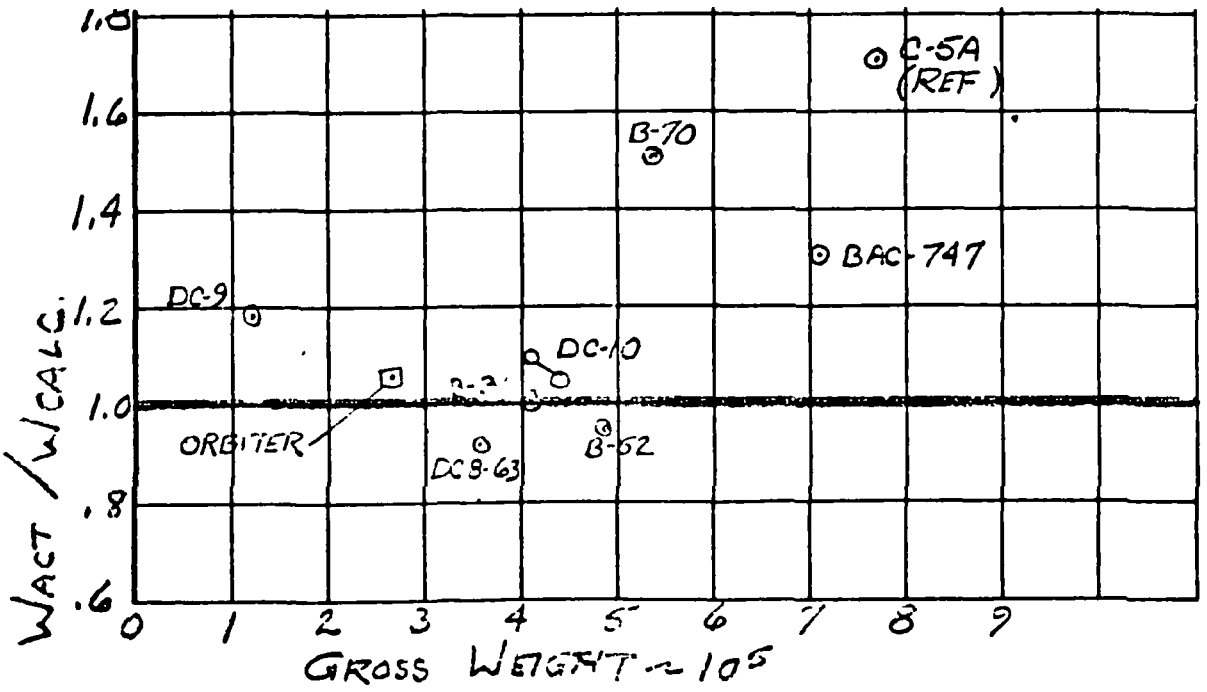
- o The C-5A is a very sophisticated gear including kneeling, extending, elaborate folding, cross wind landing and rough field operation, thus, it should be heavier than "standard" gears.
- o BAC 747 is based on limited data and may not be completely accurate
- o The B-70 gear was a boiler plate design, including a skid to prevent strut damage in case of a tire failure. This minimum cost design approach should be heavier than "standard" gears.
- o No trend with either length or load is obvious.

It is concluded that the McAIR 747 gear equations are reasonably valid for large A/C with "long" gear and should be used for Shuttle analysis until detail designs are developed.

MCAIR PREDICTED WEIGHT vs GEAR LENGTH



MCAIR PREDICTED WEIGHT vs GROSS WEIGHT



ALIGHTING GEAR GROUP EQUATIONS

In gen ral the discussion of the equations which follows holds for both nose and ma n gear. The exceptions being where certain items are not applicable to both.

STRUCTURE

The structure as defined here is the struts (including the oil), bogey beams, axles and attach fittings. Strut weight is computed as a function of maximum strut reaction, length and material properties. Bogey beam weight is a function of the load and beam length (expressed in terms of tire diameter). The axle weight (required only when more than one wheel is used per strut) is a function of load and length (expressed in terms of the tire width). The attach fitting weight is a function of the strut weight.

Main Gear

$$G(1) = G(S) + G(BB) + G(A) + G(F)$$

$$G(S) - \text{STRUTS} = 4.45\left[(LMGSE) + .3\,(LSM)\right]^{.95}(RBM)^{.68}\left[(EM)\,(FVMGS)\right]^{.6}(KMM)\,(NSM)$$

$$G(BB) - \text{BOGEY BEAMS} = .891\,(DTM)^{1.4}\,(FVMGS)^{.7}\,(NSM)$$

$$G(A) - \text{AXLES} = 1.425\,(WTM)^{1.4}\,(FVMGS)^{.7}\,(NSM)$$

$$G(F) - \text{ATTACH FITTING} = .06\left(G(S)\right)^{1.1}$$

Nose Gear

$$G(4) = G(NS) + G(NF)$$

$$G(NS) - \text{STRUTS} = 8.64\left[(LNGSE) + .3\,(LSN)\right]^{.91}(RBN)^{.68}\left[(EN)\,(FVNGS)\right]^{.45}(KMN)\,(NSN)$$

$$G(NF) - \text{ATTACH FITTING} = .06\left(G\,(NS)\right)^{1.1}$$

RUNNING GEAR

Wheel and tire weights of the running gear are estimated in relation to their geometry and load capacity. The brake weight is computed from the design landing kinetic energy. The air and anti-skid device weights are estimated without the aid of equations.

Main Gear

$$G(2) = G(W) + G(B) + G(T) + G(AS)$$

$$G(W) - \text{WHEELS} = 5.02\,(F/NWM)^{.59}\,(DWM)^{.7}\,(WFM)^{.94}\,(NWM)$$

$$G(B) - \text{BRAKES} = KB(KE)^{N}$$

G(T) – TIRES

TUBELESS = $2.71\ (DTM + DWM)^{.96}\ (WTM + DTM - DWM)^{.864}\ (FWM)^{.384}\ (NWM)$

LOW PROFILE = $1.27\ (DTM + DWM)^{1.17}\ (WTM + DTM - DWM)^{1.053}\ (FWM)^{.468}\ (NWM)$

AIR WEIGHT = ESTIMATED

G(AS) – WEIGHT ANTI-SKID DEVICE – WASD

Nose Gear

$G(5) = G(NW) + G(NT)$

G(NW) – NOSE WHEELS = $9.21\ (F/NWN)^{.33}\ (DWN)^{.7}\ (WFN)^{.94}\ (NWN)$

G(NT) – NOSE TIRES

TUBLESSS = $2.71\ (DTN + DWN)^{.96}\ (WTN + DTN - DWN)^{.864}\ (FWN)^{.384}\ (NWN)$

LOW PROFILE = $1.27\ (DTN + DWN)^{1.17}\ (WTN + DTN - DWN)^{1.053}\ (FWN)^{.468}\ (NWN)$

AIR WEIGHT = ESTIMATED

CONTROLS

The controls weight covers those items required for operation of the gear. The weight is a function of the structure and running gear weight.

Special increments are required to account for such features as sky hook, tip skids, tail bumpers, tip protection gear and etc. These items are not considered a part of either main gear or nose gear, but are usually included in the landing gear group total weight.

Main Gear

$$G(3) = .225\left[G(1) + G(2)\right]^{.95}$$

Nose Gear

$$G(6) = KC\left[G(4) + G(5)\right]^{.80}$$

MAIN LANDING GEAR – STRUCTURE

G(S) – STRUTS = 4.45(LMGSE∘.3(LSM))∗∗.95(RBM∗∗.60)(((EM)(FVMGS))∗∗.6)(KMM)(NSM)

RBM(TAXING) = LCGM/(LCGM + LBDM)

RBM(LANDING) = (LMGSE −0.5(SM))/(LMGSE + LBDM −0.5(SM))

EM(MATERIAL EFFICIENCY) =(RHOM/FAM)/.001

MODEL	CONDITION	RHOM	FAM	EM	FVMGS	KMM	LMGSE	LCGM	LBDM	LSM	SM	RBM	NSM	G(S)
FH-1	LANDING	C.283	17C.0	1.66	28.55	1.00	3.26	2.34	1.67	0.0	C.92	0.626	2.00	201.82
F2H-1	LANDING	C.283	17C.0	1.66	37.42	1.00	3.57	2.57	1.21	0.70	1.00	0.717	2.00	299.62
F2H-2	LANDING	0.283	17C.C	1.66	52.0C	1.00	3.57	2.57	1.19	0.70	1.00	0.721	2.00	366.16
F2H-3	LANDINC	C.283	2CC.0	1.41	78.80	1.00	3.57	2.58	1.19	0.78	1.00	0.721	2.00	428.79
F3H-1N	LANDING	C.283	2CC.0	1.41	83.96	1.00	4.67	3.50	1.58	0.50	1.17	0.721	2.00	557.61
F3H-2	LANCING	C.283	2CC.0	1.41	83.96	1.00	4.67	3.50	1.49	0.50	1.17	C.733	2.00	564.12
F4H-1	LANCING	C.283	22C.C	1.29	92.90	1.00	4.95	3.78	1.25	0.21	1.17	0.777	2.00	611.63
F4H-1 SBL	ANDING	C.283	232.0	1.22	135.00	1.00	5.12	3.80	1.32	0.21	1.33	0.771	2.00	761.26
XF-88	CROUNC	C.283	18C.0	1.57	34.50	1.00	4.80	4.05	2.12	0.0	C.75	C.656	2.00	325.72
F-1C1A	GPCUNC	C.2d3	2CC.0	1.41	68.00	1.00	5.74	4.73	2.00	0.0	1.01	C.703	2.00	570.39
F-1C1C	GPCUNC	C.28?	2CC.C	1.41	68.00	1.00	5.74	4.73	2.00	0.0	1.01	0.703	2.CO	570.39

MAIN LANDING GEAR - STRUCTURE (CONT'D)

G(F) - ATTACH FITTINGS = 0.06(G(S))**1.1

G(I) - STRUCTURE = G(S) + G(BB) + G(A) + G(F)

MODEL	G(S)	G(BB)	G(A)	G(F)	G(I)
FH-1	201.82	C.0	0.0	20.59	222.41
F2H-1	299.62	C.0	0.0	31.80	331.41
F2H-2	366.16	0.0	0.0	39.64	405.80
F2H-3	428.75	C.0	0.0	47.16	475.95
F3H-1N	557.61	0.0	0.0	62.97	620.57
F3H-2	564.12	C.0	C.0	63.78	627.90
F4H-1	611.63	C.0	0.0	69.71	681.34
F4H-1 98	761.26	C.0	0.0	88.68	849.94
XF-88	325.72	C.0	0.0	34.86	360.58
F-101A	570.39	C.0	0.0	64.56	634.94
F-101C	570.39	C.0	0.0	64.56	634.94

MAIN LANDING GEAR - RUNNING GEAR

G(W) - WHEELS = 5.02((F/NWM)**.59)(DWM**.7)(WFM**.94)(NWM)

F (TOTAL WHEEL LOAD) = THE LARGER OF (WL)*(NL) or (WM)*(NT)

MODEL	CONDITION	WM	NT	WL	NL	F	NWM	DWM	WFM	G(W)
FH-1	LANDING	11.55	3.00	8.20	5.10	41.82	2.00	1.22	0.48	34.84
F2H-1	LANDING	16.16	3.00	11.60	6.00	69.60	2.00	1.17	C.42	39.83
F2H-2	LANDING	22.32	3.00	15.30	7.05	107.86	2.00	1.17	C.42	51.57
F2H-3	LANDING	26.20	3.00	16.70	9.00	150.30	2.00	1.17	0.42	63.40
F3H-1N	LANDING	33.97	3.00	23.50	8.13	191.05	2.00	1.33	C.50	94.13
F3H-2	LANDING	36.52	3.00	23.50	8.13	191.05	2.00	1.33	C.50	94.13
F4H-1	LANDING	40.29	3.00	28.00	7.24	202.72	2.00	1.33	C.50	97.48
F4H-1 98	LANDING	43.59	3.00	34.00	7.58	257.72	2.00	1.33	0.50	112.31
XF-88	GROUND	25.58	3.00	14.30	4.60	76.74	2.00	1.30	C.58	62.18
F-101A	GROUND	50.37	3.00	33.00	3.70	151.12	2.00	1.33	C.58	94.24
F-101C	GROUND	51.00	3.00	33.00	3.70	152.99	2.00	1.33	C.58	94.93

MAIN LANDING GEAR - RUNNING GEAR

G(B) - BRAKES = KB(KE**N)

KE = 58.7(WL)(VSL**2)

MODEL	KB	KE	N	VSL	WL	G(B)
FH-1	11.8C	2.3C	0.91C	69.20	8.20	25.23
F2H-1	11.8C	6.02	0.91C	94.00	11.60	60.41
F2H-2	11.6C	7.64	C.91C	94.00	15.30	77.71
F2H-3	11.8C	8.66	0.91C	94.00	16.70	84.16
F3H-1N	11.8C	13.52	0.91C	99.00	23.50	126.20
F3H-2	11.3C	12.19	C.910	94.00	23.50	114.84
F4H-1	11.8O	13.47	C.91C	106.00	28.00	167.61
F4H-1 GB	11.8C	27.32	C.91C	117.00	34.00	239.38
XF-8B	4.6C	11.3C	1.176	116.00	14.30	79.61
F-101A	4.6C	36.36	1.176	137.00	33.00	314.79
F-101C	4.6C	38.51	1.176	141.00	33.00	336.83

MAIN LANDING GEAR - RUNNING GEAR (CONT'D)

G(AS) - ANTI-SKID DEVICE = ESTIMATED

MODEL	G(AS)
F-101A	12.32
F-101C	12.32

MAIN LANDING GEAR - RUNNING GEAR (CONT'D)

G(T) - TIRES

TUBELESS = 2.71((DTM+DWP)**.96)((WTP+DTM-DWM)**.864)(FWM**.384)(NWM)

LOW PROFILE = 1.27((DTM+DWP)**1.17)((WTM+DTM-DWM)**1.053)(FWM**.468)(NWM)

FWM = C.90*(WP)/(NWM)

AIR WEIGHT = ESTIMATED

MODEL	TIRE TYPE	DTM	DWP	WTP	FWM	NWM	WA	G(T)
FW-1	LOW PROFILE	2.16	1.22	C.48	9.38	2.00	1.00	34.83
F2W-1	LOW PROFILE	2.14	1.17	0.55	7.27	2.00	1.00	41.89
F2W-2	LOW PROFILE	2.14	1.17	0.55	10.04	2.00	1.00	48.56
F2W-3	LOW PROFILE	2.14	1.17	0.59	11.70	2.00	2.84	53.65
F3W-1N	LOW PROFILE	2.48	1.33	0.65	15.29	2.00	2.00	80.87
F3W-2	TUBELESS	2.45	1.33	0.65	16.61	2.00	2.00	95.79
F4W-1	TUBELESS	2.45	1.33	0.65	18.13	2.00	2.00	98.99
F4W-1	98TUBELESS	2.49	1.33	0.65	19.62	2.00	2.00	101.96
YC-8P	LOW PROFILE	2.58	1.30	0.74	11.51	2.00	2.00	83.64
F-101A	LOW PROFILE	2.67	1.33	0.74	22.67	2.00	3.00	122.81
F-101C	LOW PROFILE	2.67	1.33	0.74	22.95	2.00	3.00	123.50

MAIN LANDING GEAR - RUNNING GEAR (CONT'D)

G(2) - TOTAL RUNNING GEAR PROVISIONS

MODEL	G(W)	+ G(R)	+ G(T)	+ G(AS)	= G(2)
FH-1	34.84	25.23	34.83	0.0	94.90
F2H-1	39.83	60.41	41.89	0.0	142.13
F2H-2	51.57	77.71	48.56	0.0	177.85
F2H-3	63.40	84.16	53.65	0.0	201.22
F3H-1N	94.13	126.20	80.87	0.0	301.20
F3H-2	94.13	114.84	95.79	0.0	304.76
F4H-1	97.48	167.61	98.99	0.0	364.08
F4H-1 SP	112.21	239.36	101.96	0.0	453.66
XF-88	62.18	79.61	83.64	0.0	225.43
F-101A	94.24	314.79	122.81	12.32	544.16
F-101C	94.53	336.83	123.50	12.32	567.58

MAIN LANDING GEAR - CONTROLS

G(3) = .225(G(1) + G(2))**.95

MODEL	G(1)	G(2)	G(3)
FH-1	222.41	94.90	53.53
F2H-1	331.41	142.13	78.30
F2H-2	405.80	177.85	95.51
F2H-3	475.88	201.22	109.55
F3H-1N	620.57	301.20	147.43
F3H-2	627.90	304.76	149.08
F4H-1	681.34	364.08	166.15
F4H-1 SP	849.54	453.66	204.91
XF-88	360.58	225.43	95.87
F-101A	834.54	544.16	186.28
F-101C	834.54	567.58	189.75

NOSE LANDING GEAR - STRUCTURE

G(NS) - STRUTS = 8.64((LNGSE+.3(LSN))**.91)(RBN**.68)(((EN)(FVNGS))**.45)(KMA)(NSN)

RBN(TAXING) = LOGN/(LOGN + LBGN)

RBN(LANDING) = (LNGSE -0.5(SN))/(LNGSE + LBGN -0.5(SN))

EN(MATERIAL EFFICIENCY) = (RHOP/FAN)/.001

MODEL	CONDITION	RHON	FAN	EN	FVNGS	KMA	LNGSE	LOGN	LBGN	LSN	SN	RBN	NSN	G(NS)
F4-1	LANDING	0.283	170.0	1.66	8.80	1.00	3.70	2.78	0.83	0.0	0.92	0.796	1.00	81.44
F2H-1	LANDING	0.283	170.0	1.66	22.40	1.00	3.08	2.16	0.92	0.0	0.90	0.741	1.00	99.94
F2H-2	LANDING	0.283	170.0	1.66	22.40	1.00	3.08	2.16	0.92	0.0	0.90	0.741	1.00	99.94
F2H-3	LANDING	0.283	200.0	1.41	31.90	1.00	4.48	2.81	1.38	1.17	1.68	0.725	1.00	161.66
F3H-1N	LANDING	0.283	200.0	1.41	47.60	1.00	6.56	4.56	2.51	0.83	2.00	0.689	1.00	255.48
F3H-2	LANDING	0.283	200.0	1.41	47.60	1.00	6.56	4.56	2.51	0.83	2.00	0.689	1.00	255.48
F4H-1	LANDING	0.283	220.0	1.29	59.90	0.82	6.01	4.01	1.38	0.29	2.00	0.784	1.00	219.78
F4H-1 98	LANDING	0.283	220.0	1.29	68.00	0.82	6.01	4.01	1.38	0.29	2.00	0.784	1.00	232.69
XF-8A	GROUND	0.283	170.0	1.66	11.50	1.00	4.00	3.25	1.35	0.0	0.75	0.707	1.00	90.93
F-101A	GROUND	0.100	75.0	1.33	22.67	1.00	4.36	3.61	1.85	0.0	0.75	0.661	1.00	115.46
F-101C	GROUND	0.100	75.0	1.33	22.67	1.00	4.36	3.61	1.85	0.0	0.75	0.661	1.00	115.46

NOSE LANDING GEAR - STRUCTURE (CONT'D)

G(NF) - ATTACH FITTINGS = 0.06(G(AS))**1.1

G(4) - STRUCTURE = G(AS) + G(NF)

MODEL	G(NS)	G(NF)	G(4)
FH-1	81.44	7.59	89.03
F2H-1	99.54	9.90	109.44
F2H-2	99.54	9.90	109.44
F2H-3	161.66	16.13	177.79
F3H-1N	255.48	26.68	282.16
F3H-2	255.48	26.68	282.16
F4H-1	219.78	22.61	242.39
F4H-1 SB	232.65	24.08	256.76
XF-8B	90.93	8.57	99.50
F-101A	115.46	11.14	126.60
F-101C	115.46	11.14	126.60

NOSE LANDING GEAR - RUNNING GEAR

G(NW) - WHEELS = 5.21((F/NWN)**.33)(DWN**.7)(WFN**.94)(NWN)

F (TOTAL WHEEL LOAD) = THE LARGER OF (WL)*(AL) or (WP)*(AT)

MODEL	CONDITION	WP	NT	WL	AL	F	NWN	DWN	WFN	G(NW)
FH-1	LANDING	11.95	3.00	8.20	5.10	41.82	1.00	0.83	0.36	10.65
F2H-1	LANDING	16.16	3.00	11.60	6.00	69.60	1.00	0.95	0.38	14.70
F2H-2	LANDING	22.32	3.00	15.30	7.05	107.86	1.00	0.95	0.35	15.53
F2H-3	LANDING	26.20	3.00	16.70	9.00	150.30	1.00	1.00	0.35	17.95
F3H-1N	LANDING	33.57	3.00	23.50	8.13	191.05	1.00	1.17	0.35	21.88
F3H-2	LANDING	36.52	3.00	23.50	8.13	191.05	1.00	1.17	0.35	21.88
F4H-1	LANDING	40.29	3.00	28.00	7.24	202.72	2.00	0.67	0.35	24.07
F4H-1 SB	LANDING	43.59	3.00	34.00	7.58	257.72	2.00	0.67	0.35	26.06
XF-8B	GROUND	25.59	3.00	14.30	4.60	76.74	1.00	0.83	0.58	20.29
F-101A	GROUND	50.37	3.00	33.00	3.70	151.12	2.00	0.66	0.35	21.39
F-101C	GROUND	51.00	3.00	33.00	3.70	152.99	2.00	0.66	0.35	21.48

NOSE LANDING GEAR - RUNNING GEAR (CONT'D)

G(NT) - TIRES

TUBELESS = 2.71((DTA+DWA)**.96)((WTN+DTN-DWN)**.864)(FWN**.384)(NWN)

LOW PROFILE = 1.27((DTA+DWA)**1.17)((WTN+DTN-DWN)**1.053(FWN**.468)(NWN)

FWN = 0.15*(WP)/(NWN)

AIR WEIGHT = ESTIMATED

MODEL	TIRE TYPE	DTN	DWN	WTA	FWN	NWN	WA	G(NT)
FH-1	LOW PROFILE	1.66	0.83	0.57	1.79	1.00	0.40	7.32
F2H-1	LOW PROFILE	1.86	0.95	0.58	2.42	1.00	0.50	10.29
F2H-2	LOW PROFILE	1.86	0.95	0.48	3.35	1.00	0.50	11.09
F2H-3	LOW PROFILE	1.85	1.00	0.48	3.93	1.00	0.50	11.58
F3H-1N	LOW PROFILE	2.01	1.17	0.47	5.10	1.00	1.00	15.07
F3H-2	TUBELESS	2.01	1.17	0.47	5.54	1.00	1.00	21.13
F4H-1	TUBELESS	1.49	0.67	0.47	3.02	2.00	1.00	22.70
F4H-1 98	TUBELESS	1.49	0.67	0.47	3.27	2.00	1.00	23.37
XF-88	LOW PROFILE	2.00	0.93	0.74	3.84	1.00	0.50	16.41
F-101A	LOW PROFILE	1.50	0.96	0.48	3.78	2.00	1.00	16.61
F-101C	LOW PROFILE	1.50	0.66	0.48	3.82	2.00	1.00	16.70

NOSE LANDING GEAR - RUNNING GEAR (CONT'D)

G(S) - TOTAL RUNNING GEAR PROVISIONS

MODEL	G(NW)	+ G(NT)	= G(S)
FH-1	10.65	7.32	17.97
F2H-1	14.70	10.29	25.00
F2H-2	15.53	11.09	26.62
F2H-3	17.58	11.58	29.53
F3H-1N	21.88	15.07	36.95
F3H-2	21.88	21.13	43.02
F4H-1	24.07	22.70	46.78
F4H-1 98	26.06	23.37	49.43
XF-88	20.29	16.41	36.70
F-101A	21.39	16.61	38.00
F-101C	21.48	16.70	38.17

SPECIAL INCREMENT - ALIGHTING GEAR - TAIL BUMPER

S(1) = CONST1(A**E1)

A = WEIGHT INCREMENT FROM ACT. WT. RPT.-LBS. E1 = 1.000

MODEL	CONST1	A	S(1)
F2H-1	1.00	4.00	4.00
XF-88	1.00	6.00	6.00

SPECIAL INCREMENT - ALIGHTING GEAR - WING AND/OR TAIL SKID PROV.

S(2) = CONST1(A**E1)

A = ACT.WT.FROM RPT.-LBS E1 = 1.000

MODEL	CONST1	A	S(2)
F2H-2	1.00	6.00	6.00
F2H-3	1.00	7.00	7.00
F3H-1N	1.00	45.00	45.00
F3H-2	1.00	54.00	54.00

SPECIAL INCREMENT - ALIGHTING GEAR - SHIMMY DAMPER

S(3) = CONST1(A**E1)

A = ACTUAL WEIGHT FROM REPORT - LBS. E1 = 1.000

MODEL	CONST1	A	S(3)
F2H-3	1.00	11.60	11.60

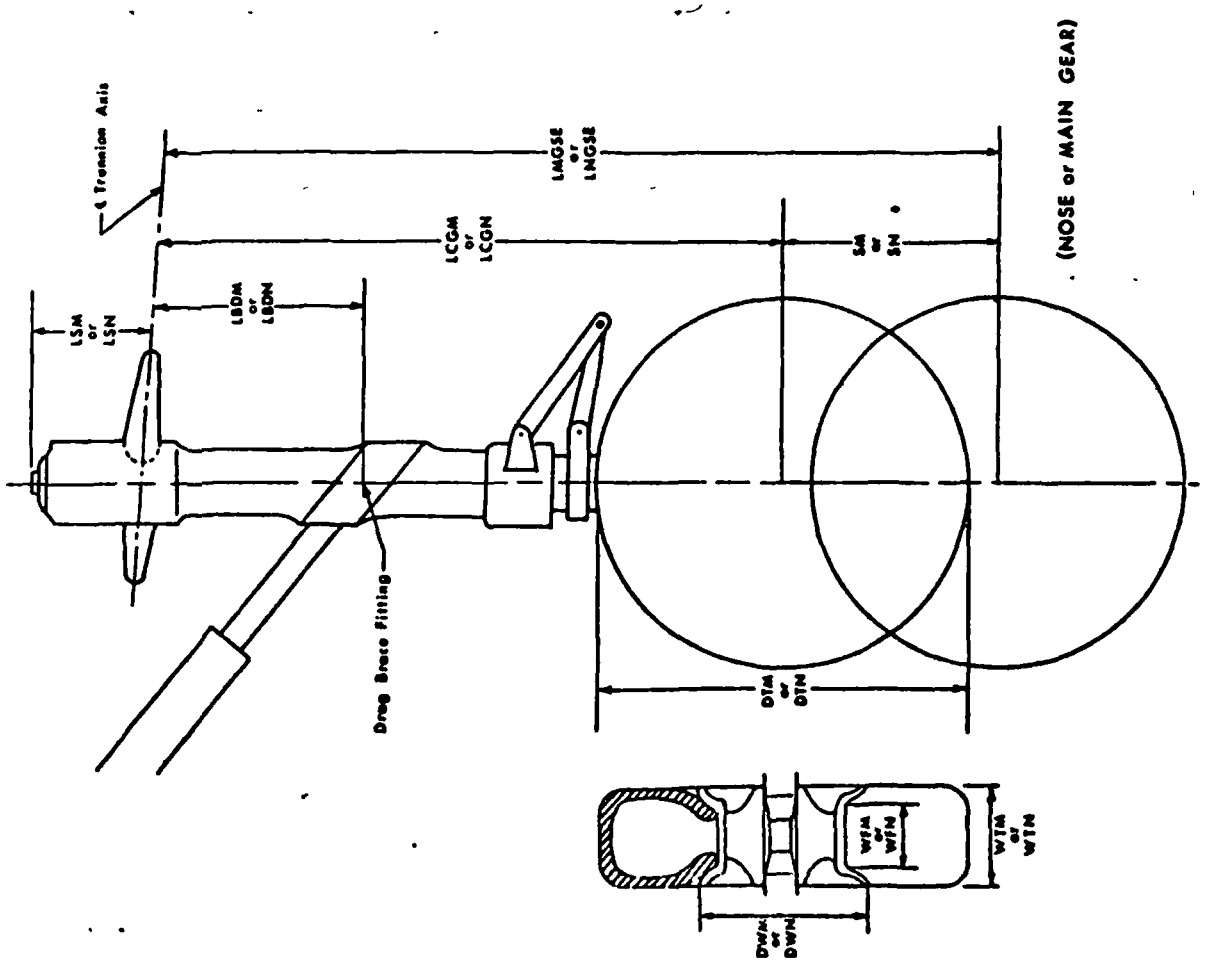
NOSE LANDING GEAR - CONTROLS

G(6) - CONTROLS = KC(G(4) + G(5))**.80

MODEL	KC	G(4)	G(5)	G(6)
F4H-1	0.53	85.03	17.97	22.27
F2H-1	0.53	100.44	25.00	26.74
F2H-2	0.53	100.44	26.62	26.99
F2H-3	0.53	177.75	25.53	37.81
F3H-1N	0.53	292.16	36.55	53.39
F3H-2	0.53	292.16	43.02	54.20
F4H-1	0.53	242.35	46.78	49.34
F4H-1 CR	0.53	254.76	49.43	51.65
XF-88	1.20	63.50	36.70	61.17
F-101A	1.00	126.40	38.00	71.17
F-101C	1.00	122.60	38.17	71.23

ALIGHTING GEAR GROUP PARAMETER LISTING

Note	All lengths are to be measured along centerline of strut	Nose Gear	Main Gear	
	Maximum outside tire diameter - feet	DTN	DTM	
	Wheel bead ledge diameter - feet	DWN	DWM	
	Material Efficiency Main Gear RHOM/FAM In^{-1} x 10^{3} Nose Gear RAMS/FAS In^{-1} x 10^{3} Where FAM, FAM Allowable Material Stress of primary strut material kilopounds/sq in RHOM, RHOM density of primary strut material - pounds/cu in.	EM EN		
	Total wheel load - ult - pounds/1000 Use larger of: P = (NL)(NL) P = (NM)(MT) Where NL Ultimate landing load factor MT Ultimate taxi load factor WL Landing gross weight - pounds/1000 WM Maximum takeoff gross weight - pounds/1000	P		
	Maximum ultimate vertical load per strut - pounds/1000	PNOS	PMOS	
	Load per tire Main gear .90 (WM)/RGM - pounds/1000 Nose gear .15 (WM)/RGN - pounds/1000	PNI	PMI	
	Constant: Brake Air Force = 1.6 Bay = 11.8	KB		
	Nose Gear Control Constant Air Force = 1.20 Bay = 0.53	KC		
	Kinetic energy landing design - FL pounds/10^{6} = 30.7 (WL)(VL)^{2} Where VL power off stall speed - knots WL landing gross weight - pounds/1000	KE		
	Outgo barrel material factor 0.62 for aluminum 1.00 for steel	KNM	KMM	
	Brace distance length - feet (Trunnion to drag brace fitting)	LBSN	LBSM	
	Collapsed gear length - feet (Trunnion to axle)	LCSN	LCSM	
	Length of extended gear strut - feet (Measured from the trunnion centerline to the axle centerline along the strut centerline)	LNGSE	LMGSE	
	Length of strut above trunnion - feet	LSN	LSM	
	Brake exponent Air Force = 1.176 Bay = 0.91	n		
	Number of struts per aircraft	NSN	NSM	
	Number of wheels per aircraft	NWN	NWM	
	Brace ratio P = (WL)(F) Ground condition BRN = .5GN/(LGN + LSN) BRM = .5GM/(LGM + LSM) P = (WL)(SF) Landing condition BRN = (5NSE - .5 SN)/(LNSE + LBSN - .5 BN) BRM = (5MSE - .5 SM)/(LMSE + LBSM - .5 BM)	BRN BRM		
	Total gear stroke - feet	SN	SM	
	Weight of air in tires - pounds	WAN	WAM	
	Weight of anti-skid device - pounds	WASD		
	Wheel flange width - feet	WFN	WFM	
	Maximum tire section width - feet	WTN	WTM	



2.6 Propulsion - Main Ascent	26637	Lb

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Section 2.6

The main propulsion system weight was calculated using drawing number 255BJ50069 Rev. A and the propulsion system schematic. Weight was included for couplings, supports, wiring and installation parts where experience indicates these items will be required.

A contingency was added to the total system weight to provide for items which may have been overlooked. Experience indicates, as shown in section 1, that a contingency allowance is needed at this stage of design maturity to assure a 50% probability that the weight will not be exceeded.

The following notes apply to this section:

- The main ascent engine weight was taken from the CEI specification, Space Shuttle Main Engine 550K (SL) dated 1 March 1971.
- The gimbal actuator weights were provided by hydraulic specialists and verified using the method described in section 2.12, Surface Control.
- The stage pneumatic system provides the pneumatic power for main engine control. This system also provides pneumatic control for the auxiliary and cruise propulsion systems. It also provides pressurization gas for the cruise fuel tanks.
- Valve weights are based on correlated data presented on pages 2.6-14 thru 2.6-16.
- Angulation and sliding joint weights are based on the method presented on pages 2.6-17 thru 2.6-23.
- Coupling weights were derived from vendor catalog data and include flanges, seals and coupling devices.
- A LOX line diameter of 18 inch is required so that acceleration pressure losses during the zero-g start do not decrease the engine inlet pressure below that required for Net Positive Suction Head.
- The LH_2 line diameters are not set by the start conditions since the line length is quite short. A 12 inch diameter was determined by design considerations (diffuser section half angle) involved in transitioning to the 15 inch engine inlet duct.

MAIN ASCENT PROPULSION

SUMMARY

6 PROPULSION – MAIN ASCENT					26637
ENGINE & ACCESSORIES				19422	
ENGINE (AS SUPPLIED)			17620		
GIMBAL SYSTEM			709		
IGNITION AND CONTROL SYSTEM			833		
PROPELLANT UTILIZATION SY			260		
ACCESSORIES			N/A		
INSTALLATION, DUCTS, SHROUDS					
PROPELLANT SY		FUEL	OXIDIZER	6206	
FILL/DRAIN		170	120		
PRESSURIZATION/VENT		1242	616		
RECIRCULATION		93	90		
PCV SY		0	0		
PRE-VALVES		334	528		
FEED SYSTEMS		512	2059		
VORTEX, FLOW CONTROL SYSTEM		223	219		
TANKAGE – NONINTEGRAL	TANK	INSULATE	SUPTS		
FUEL	N/A	N/A	N/A		
OXIDIZER	N/A	N/A	N/A		
CONTINGENCY				1009	

DESIGN DATA SUMMARY

6 PROPULSION – MAIN ASCENT	THRUST-SL	THRUST-VAC	EXP RATIO	I_{sp} VAC	CHAMB PRES PSI
ENGINE	550K	632K	150	459	3000

PROPELLANT SYSTEM	FUEL	OXIDIZER	
ULLAGE PRES – PSI	30	30	(OPERATING LIMIT)
PROPEL TYPE	LH2	LOX	
ULLAGE VOL – FT^3	538	189	(727)
PRESSURANT	GH2	GOX	
TOTAL TANK VOL – FT^3 *	18524	6874	(25398)
USABLE PROP VOL – FT^3 **	17986	6685	(24671)
TOTAL LEN OF FEEDLINES – FT	27	195	

* NET USABLE PLUS ULLAGE (INCLUDES FEED LINE AND ENGINE VOLUME)
** INCLUDES FEED LINE AND ENGINE VOLUME

NOTE: SEE DWG. NO. 255BJ50069 (PAGE 2.6-24)

GIMBAL SYSTEM

	QTY	WT.~LB
ACTUATORS (SEE SECTION 2.12)	(4) @ 141. LB	564.0
MECHANICAL LINKS (SEC. ACT. TO ACTUATOR)	(4) @ .75 LB	3.0
FTGS (SEC. ACT.)	(4) @ 3.4 LB	13.6
GIMBAL ACTUATOR SUPPORT FTGS	(4) @ 20.4 LB	81.6
PRESSURE LINES & FITTINGS 1/2 IN, .022 Ti		15.0
RETURN LINES & FITTINGS 1/2 IN, .020 Al		9.0
CIRCUITRY		23.0
TOTAL GIMBAL SYSTEM		709.2

NOTE: FOR DESIGN DATA SEE SECTIONS 2.11 & 2.12

IGNITION & CONTROL SYSTEM

PAGE 1 OF 2

WT.~LB

PNEUMATIC SYSTEM

TANK, STAGE PNEUMATIC SUPPLY (4 TANKS) 6AL4V Ti — 477.0

PRESS = 4500 PSI MAX. OPERATING; 9000 PSI BURST
I.D. = 24.58 IN. AREA = $4\pi R^2 = 1954.$ IN.^{2}

$$t = \frac{\text{BURST PRESS} * R}{2 * FTU} = \frac{9000 * 12.47}{2 * 160{,}000.} = .351$$

WT. = NON-OPT. * t * AREA * ρ
= 1.08 * .315 * 1954. * .161 = 119.26 LB
VOL. = $4/3\ \pi R^2$ = 4.500 CU. FT. EA.

ACCUMULATORS, STAGE PNEUMATIC SUPPLY (3 TANKS) 6AL4V Ti — 8.3

PRESS = 750 PSI MAX. OPERATING; 1500 PSI BURST
I.D. = 11.6 IN. AREA = $4\pi R^2 = 425$ IN.^{2}

$$t = \frac{1500 * 5.81}{2 * 160{,}000} = .027$$

WT = 1.5 * .027 * 425. * .161 = 2.77 LB EA
VOL. = $4/3\ \pi R^2$ = .473 CU. FT. EA.

ACCUMULATOR, ENGINE PNEUMATIC SUPPLY (1 TANK) 6AL4V Ti — 3.2

PRESS = 850 PSI MAX. OPERATING & 1700 PSI BURST
I.D. = 11.6 IN. AREA = $4\pi R^2 = 425$ IN.^{2}

$$t = \frac{1700 * 5.81}{2 * 160{,}000} = .031$$

WT. = 1.5 * .031 * 425 * .161 = 3.18 LB
VOL = $4/3\ \pi R^2$ = .473 CU. FT. EA.

TANK SUPPORTS & MISC. — 37.0

IGNITION & CONTROL SYSTEM

PAGE 2 OF 2

	QTY	UNIT WT-LB	WT.-LB
PNEUMATIC SYSTEM			
VALVES, FILTERS & ORIFICES			
FILL VALVE 1/2 IN. LINE DIA.	(1)	@ .75	.8
CHECK VALVES 1/4 IN. LINE DIA.	(4)	@ .15	.6
FILTERS 1/2 IN. LINE DIA.	(7)	@ 1.50	10.5
FILTERS 1 1/2 IN. LINE DIA.	(3)	@ 8.50	25.5
N.C. SOLENOID VALVES 1/2 IN. LINE DIA.	(7)	@ 1.00	7.0
HAND VALVES 1/4 IN. LINE DIA.	(2)	@ .25	.5
CHECK VALVES 1/2 IN. LINE DIA.	(4)	@ .33	1.3
REGULATORS	(3)	@ 5.00	15.0
PNEUMATIC ACTUATOR SOLENOID VALVES	(54)	@ 1.00	54.0
BURST DISC / CHECK VALVE 1 1/2 IN. LINE DIA.	(2)	@ 3.25	6.5
BURST DISC / CHECK VALVE 1/2 IN. LINE DIA.	(4)	@ .45	1.8
N.C. SOLENOID VALVE 1 1/2 IN. LINE DIA.	(4)	@ 3.25	13.0
N.O. SOLENOID VALVE 1 IN. LINE DIA.	(4)	@ 1.60	6.4

PNEUMATIC LINES		IN.	LB/IN.	
1/4 INCH DIA, .016	S.S. P<5800 PSI. OPP.	15000.	IN. @ .0034	51.0
1/2 INCH DIA, .016	S.S. P< 2900 PSI. OPP.	400.	IN. @ .0069	2.8
1/2 INCH DIA, .028	S.S. P=4500 PSI. OPP.	500.	IN @ .0118	5.9
1 INCH DIA, .016	S.S. P= 850 PSI. OPP.	400.	IN. @ .0141	5.6
1 1/2 INCH DIA, .016	S.S. P= 850 PSI. OPP.	400.	IN @ .0212	8.5
1 1/2 INCH DIA, .083	S.S. P=4500 PSI. OPP.	50.	IN @ .1049	5.2
CONNECTORS, SUPPORTS & MISC.				55.5
IGNITION & CONTROL WIRING				
ELECTRONICS IS INCLUDED IN ENGINE WT.				
WIRING & MISC.				30.0
TOTAL IGNITION & CONTROL SYSTEM				832.9

NOTES:

- ALL PNEUMATIC SYSTEM LINES AND PNEUMATIC ACTUATOR SOLENOID VALVE WEIGHTS ARE INCLUDED IN THIS STAGE PNEUMATIC SYSTEM.

PROPELLANT UTILIZATION SYSTEM	WT. ~LB
PROPELLANT UTILIZATION ELECTRONICS ASSEMBLY	26.
INVERTER/CONVGATER	19.
LOX PROBE	40.
LH2 PROBE	96.
LEVEL SENSORS	18.
CONTROL UNITS	18.
WIRING & MISC	43.
TOTAL PROPELLANT UTILIZATION SYSTEM	260.

NOTES:

- THE PROPELLANT UTILIZATION SYSTEM WEIGHT WAS DERIVED FROM THE SIVB PROPELLANT UTILIZATION SYSTEM. SIVB WEIGHTS WERE:

P.U. ELECTRONICS	26 LB.
INVERTER/CONVERTER	19 LB.
LOX PROBE	17 LB.
LH2 PROBE	41 LB
LEVEL SENSORS	18 LB
CONTROL UNITS	18 LB.
WIRING & MISC.	20 LB
TOTAL SIIB	159 LB.

	Wt~LB
FILL & DRAIN SYSTEM	
OXIDIZER	
LINES	
4 IN. DIA. FILL & DRAIN 110 IN. LONG .050 AL	6.8
VALVES	59.0
QTY	
FILL VALVE (QUICK DISC.) 4. IN. LINE DIA. (1) @ 21.0	
N.C. PNEUMATIC (W. IND.) 4. IN. LINE DIA. (1) @ 19.0	
N.C. PNEUMATIC (W. IND.) 4. IN. LINE DIA (1) @ 19.0	
SLIDING JOINT 4 IN. DIA ±1.7 IN. (2) @ 1.5 LB EA	3.0
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS)	35.8
4 IN. DIA. AL/STL (2) @ 4.59	
4 IN. DIA STL/STL (4) @ 6.66	
SUPPORTS & MISC.	15.7
TOTAL OXIDIZER FILL, DRAIN	120.3
FUEL	
LINES	
4 IN. DIA FILL & DRAIN 220 IN. LONG .020 SS	15.8
6 IN. DIA. JACKET .012 SS — CONVOLUTED 220 IN. LONG	22.4
INSULATION 1 IN. ~ 5 LB/FT³ BETWEEN LINE & JACKET	10.0
VALVES	59.0
QTY	
FILL VALVE (QUICK DISC.) 4. IN. LINE DIA. (1) @ 21.0	
N.C. PNEUMATIC (W. IND.) 4. IN. LINE DIA. (1) @ 19.0	
N.C. PNEUMATIC (W. IND.) 4. IN LINE DIA. (1) @ 19.0	
ANGULATION JOINT. 4 IN. DIA ±5° WITH JAC (2) @ 2.4	4.8
SLIDING JOINT 4 IN. DIA ±1.7 IN. WITH JAC (1) @ 2.2	2.2
COUPLINGS	33.3
4 IN. DIA. STL/STL (5) @ 6.66	
SUPPORTS & MISC	22.1
TOTAL FUEL FILL & DRAIN	169.6

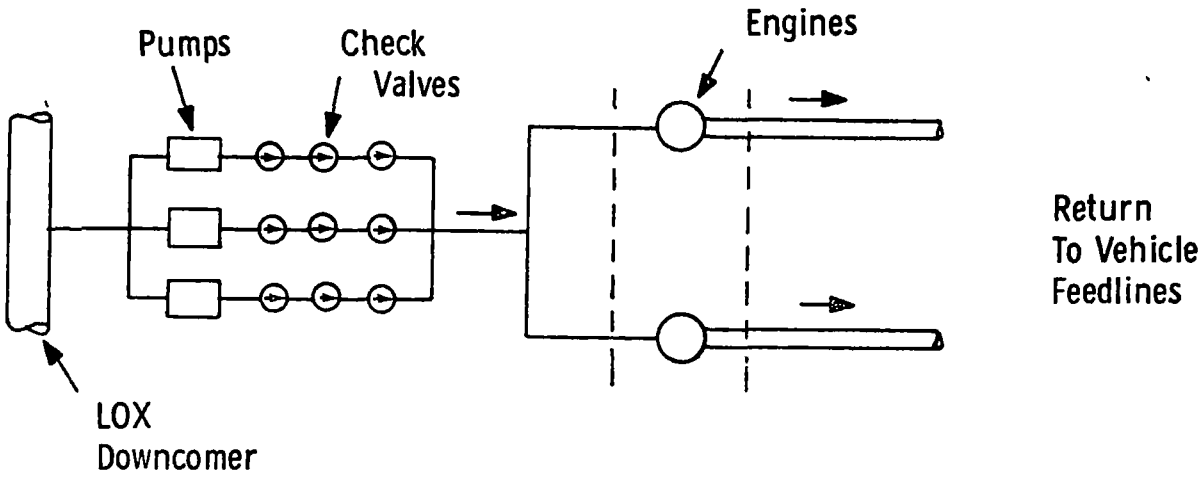
PRESSURIZATION & VENT SYSTEM
OXIDIZER

			Wt. – LB
DIFFUSER (2)		(7.37)	14.8
FLANGE 10 IN.² AL	.10	.10	
CYL BAFFLE 302 IN.² AL	.063	1.92	
SPHERICAL BAFFLE 60 IN.² AL	.063	.38	
ENDS 326 IN.² TOTAL AL	.090	1.32	
SCREEN SUPPORTS 560 IN. .0051 LB/IN. AL TUBING		2.86	
SCREEN 786 IN.² * .001 LB/IN.²		.79	
LINES			
3½ IN. DIA. DIFFUSER LINES 140 IN. LONG .028 AL.			4.3
5 IN. DIA. PRESS & VENT. LINES 2210 IN. LONG, .028 AL.			97.8
¾ IN. DIA. GROUND PREPRESS LINE 370 IN. LONG, .016 S.S.			3.9
¾ IN. DIA. ENGINE BLEED PRESS. LINE 410 IN. LONG. .016 SS.			4.3
½ IN. DIA. REPRESS LINE 500 IN. LONG .016 SS.			3.5
VALVES, FILTERS & ORFICE	QTY		259.0
FILL VALVE (QUICK DISC.) .75 IN LINE DIA.	(1)	@ 1.75 LB	
FILTER .75 IN. LINE DIA.	(1)	@ 2.80 LB	
CHECK VALVE .75 IN. LINE DIA.	(9)	@ .95 LB	
N.C. SOLENOID .75 IN. LINE DIA.	(1)	@ .95 LB	
VENT & RELIEF (W. IND) 5 IN. LINE DIA.	(2)	@ 28.00 LB	
N.C. PNEU. VALVE (W. IND) 5 IN. LINE DIA.	(1)	@ 28.00 LB	
GROUND VENT (QUICK DISC.) 5 IN. LINE DIA.	(1)	@ 30.00 LB	
N.O. PNEU VALVE (W. IND) 5 IN. LINE DIA.	(1)	@ 28.00 LB	
CHECK VALVE (NPV) 5 IN. LINE DIA.	(2)	@ 28.00 LB	
ORFICE (NPV) ASSY	(1)	@ 14.00 LB	
N.C. SOLENOID 1 IN. LINE DIA	(9)	@ 1.60 LB	
N.O. SOLENOID 1 IN. LINE DIA.	(9)	@ 1.60 LB	
N.C. SOLENOID (REPRESS) ½ IN. LINE DIA.	(9)	@ .46 LB	
SLIDING JOINTS 5 IN. DIA. ±1.7 IN. DEF.	(10)	@ 2.40 LB	24.0
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS)			123.8
3½" DIA AL/AL	(2)	@ 2.32 LB. EA	
5" DIA AL/STL	(16)	@ 5.40 "	
¾" DIA STL/STL	(18)	@ .46 "	
1" DIA STL/STL	(21)	@ .95 "	
½" DIA STL/STL	(16)	@ .28 "	
SUPPORTS & MISC			80.3
TOTAL OXIDIZER VENT & PRESSURIZATION			615.7

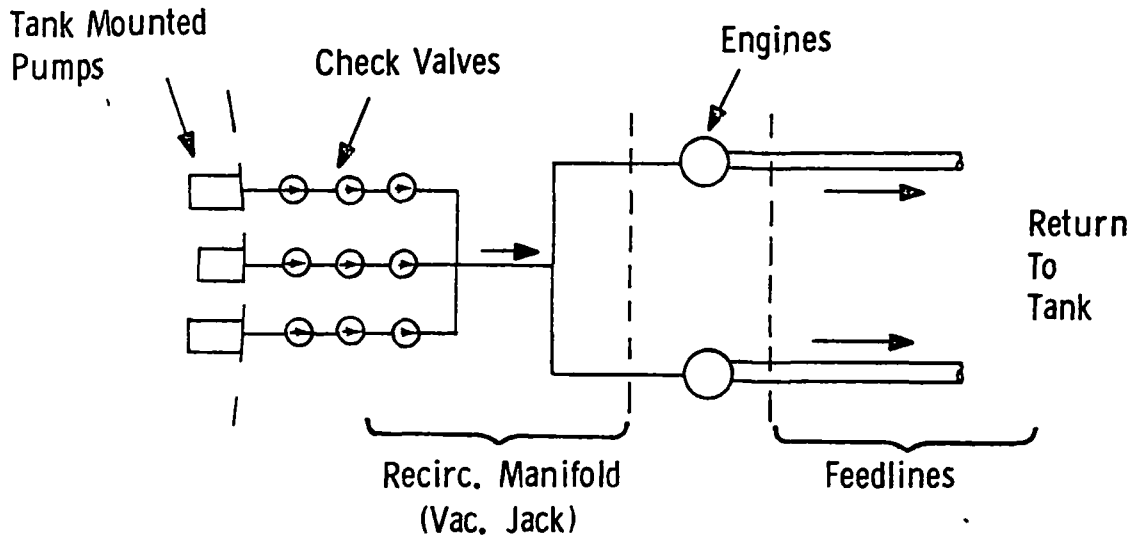
PRESSURIZATION & VENT SYSTEM FUEL

			WT. – LB.
DIFFUSERS			41.4
FLANGE 20 IN². AL	.10	2 @ .20	
CYL BAFFLE 604 IN². AL	.063	2 @ 3.84	
SPHERICAL BAFFLE 120 IN². AL	.063	2 @ .76	
ENDS 652 IN². TOTAL AL	.040	2 @ 2.64	
SCREEN SUPPORTS 1120 IN.	.0057 LB/IN. AL TUBING	@ 5.72	
SCREEN 1592 IN². * .001 LB/IN².		2 @ 1.58	
5 IN. DIA. TUBING 270 IN. LONG	.028 AL	1 @ 11.95	
LINES			
7½ IN. DIA. PRESS & VENT LINES 1248 IN. LONG	.028 AL		83.2
9½ IN. DIA. JACKET .028 AL-CONVOLUTED – 1248 IN. LONG			165.5
INSULATION 1. IN. ~ 5 LB/FT³ BETWEEN LINE & JACKET			96.4
¾ IN. DIA. GROUND PREPRESS LINE 145 IN. LONG	.016 S.S.		1.5
¾ IN. DIA. ENGINE BLEED PRESS. LINE 380 IN. LONG	.016 S.S.		4.0
½ IN. DIA. REPRESS LINE 400 IN. LONG	.016 S.S.		2.8
VALVES, FILTER & ORFICE		QTY	397.0
FILL VALVE (QUICK DISC.) .75 IN. LINE DIA.		(1) @ 1.75	
FILTER .75 IN. LINE DIA.		(1) @ 2.80	
CHECK VALVE .75 IN. LINE DIA.		(9) @ .95	
N.C. SOLENOID .75 IN. LINE DIA.		(1) @ .95	
VENT & RELIEF (W. IND.) 7.5 IN. LINE DIA.		(2) @ 55.00	
N.C. PNEUMATIC (W. IND.) 7.5 IN. LINE DIA.		(1) @ 55.00	
GROUND VENT (Q.D.) 7.5 IN. LINE DIA.		(1) @ 59.00	
N.O. PNEUMATIC (W. IND) 7.5 IN. LINE DIA.		(1) @ 55.00	
CHECK VALVE (NPV) 7.5 IN. LINE DIA.		(1) @ 55.00	
ORFICE (NPV) ASSY		(1) @ 16.00	
N.C. SOLENOID 1. IN. LINE DIA.		(9) @ 1.60	
N.O. SOLENOID 1. IN. LINE DIA.		(9) @ 1.60	
N.C. SOLENOID (REPRESS) ½ IN. LINE DIA.		(9) @ .46	
SLIDING JOINTS 7½ IN. DIA. ± 1.7 IN. DEF. W. JAC.		7 @ 8.6 LB	60.2
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS)			227.9
7½" DIA. AL/AL		(1) @ 5.34	
7½" DIA. AL/STL		(20) @ 9.49	
1" DIA. STL/STL		(21) @ .95	
¾" DIA. STL/STL		(18) @ .46	
½" DIA. STL/STL		(16) @ .28	
SUPPORTS & MISC.			162.0
TOTAL FUEL VENT & PRESSURIZATION			1241.9

ORBITER LOX - ENGINE PRESTART CONDITIONING FORCED CIRCULATION SYSTEM



ORBITER LH_2 - ENGINE PRESTART CONDITIONING FORCED CIRCULATION SYSTEM



RECIRCULATION SYSTEM

	QTY	WT – LB
OXIDIZER		
ENGINE RECIRCULATION		(74.4)
PUMPS	(3) @ 6.7 LB EA.	20.1
CHECK VALVES	(9) @ 2.0 LB EA.	18.0
LINES (INCL. FTGS. & BELLOWS)	LINES 7.7 LB, FTGS 1.6 LB, BELLOWS 20.2	29.5
SUPPORTS		6.8
MAIN FEED LINE CROSS TIE – 4 IN. DIA. –		(16.0)
ANGULATION JOINT ±5°	(1) @ 2.5 LB	2.5
SLIDING JOINT ± 1.7 IN	(1) @ 1.5 LB	1.5
COUPLINGS (DUAL CONOSEAL COUPLING ASSYS) AL/STL	(2) @ 4.59 LB	9.2
LINE 45 IN. LONG 1050 AL		2.8
TOTAL OXIDIZER RECIRCULATION SYSTEM		90.4
FUEL		
ENGINE RECIRCULATION		(92.9)
PUMPS		25.2
CHECK VALVES		18.0
LINES (INCL. JACKETS, FTGS, & BELLOWS)	LINES 29.9 LB, FTG 4.9, BELLOWS 17.9	46.7
SUPPORTS		3.0
TOTAL FUEL RECIRCULATION SYSTEM		92.9

	Wt~LB
FEED SYSTEM – LOX	
SLIDING JOINTS 18 IN. DIA ±1.7 IN. DEF. WITH LINERS 9 @ 32. LB EACH	288.
ANGULATION JOINTS 18 IN. DIA ±5° DEF. WITH LINERS 2 @ 124. LB EACH	248.
ALUMINUM DUCTS 1771. IN. TOTAL LENGTH 18 IN. DIA. .050 WALL	506.
STAINLESS STEEL DUCTS 440. IN. TOTAL LENGTH 18 IN. DIA. .050 WALL	357.
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS)	
18" DIA. AL/AL (2) @ 13.6 LB. EA.	
18" DIA AL/STL (8) @ 23.8 "	391.
18" DIA STL/STL (5) @ 34.6 "	
SUPPORTS & MISC.	269.
TOTAL OXIDIZER FEED SYSTEM	2059.
PRE VALVES – LOX	
PRE-VALVES 15 IN. DIA. (2) @ 195 LB. EA.	390.
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS) 18" DIA STL/STL (2) @ 34.6 LB. EA.	69.
SUPPORTS & MISC	69.
TOTAL OXIDIZER PRE-VALVES	528.

FEED SYSTEM – LH2	WT. ~LB
ANGULATION JOINTS 12 IN. DIA. JACKETED ± 5° DEF WITH LINERS 4 @ 27.5 LB EA.	110.
STAINLESS STEEL 12 IN. DIA. DUCTS TOTAL LENGTH = 240 IN. .050 WALL	130.
STAINLESS STEEL JACKET 14 IN. DIA. .012 CONVOLUTED TOTAL LENGTH = 240. IN. (INCL. 6 LAN; 5 LB/FT³ INSULATION)	90.
SLIDING JOINTS 12 IN. DIA. JACKETED ± 1. IN. DEF. WITH LINERS 2 @ 12.0 LB EA.	24.
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS) 12" DIA STL/STL (4) @ 22.7	91.
SUPPORTS & MISC.	67.
TOTAL FUEL FEED SYSTEM	512.
PRE VALVES LH2	
PRE-VALVES 12 IN. DIA. (2) @ 130 LB EA	260.
COUPLINGS (DUAL SEAL CONOSEAL COUPLING ASSYS) 12 IN. DIA. STL/STL (1) @ 30 LB, EA – BOLTED (1) FLANGE EACH SIDE	30.
SUPPORTS & MISC.	44.
TOTAL FUEL PRE-VALVES	334.

LH_2 ANTI-VORTEX & SUMP

		WT. – LB
SUMP – EACH –		(111.25)
12 IN. DIA. DOUBLE CONOSEAL AL. FLANGE = 10.76/2	=	5.38
28 IN. DIA. DOUBLE CONOSEAL AL. FLANGES (2) = 25.	=	25.00
CAN 26.*π*14.*.125*.101*1.15 =	=	16.70
SPIDER 3.25*28.*2.*1.*.101 =	=	18.45
BAFFLE 500*46.*2.*.25*.101 =	=	11.62
DOORS		
SCREEN 1662. IN.^{2} *.004 LB/IN^2 =	=	6.65
FRAMES (π*46+4*46)*2.*.125*.101 =	=	8.30
HINGES 2*46.*2.*.25*.101 =	=	4.65
MISC. (RNDM)	=	14.50
TOTAL FOR (2) LH_2 ANTI-VORTEX & SUMP	=	222.50

LOX ANTI-VORTEX & SUMP

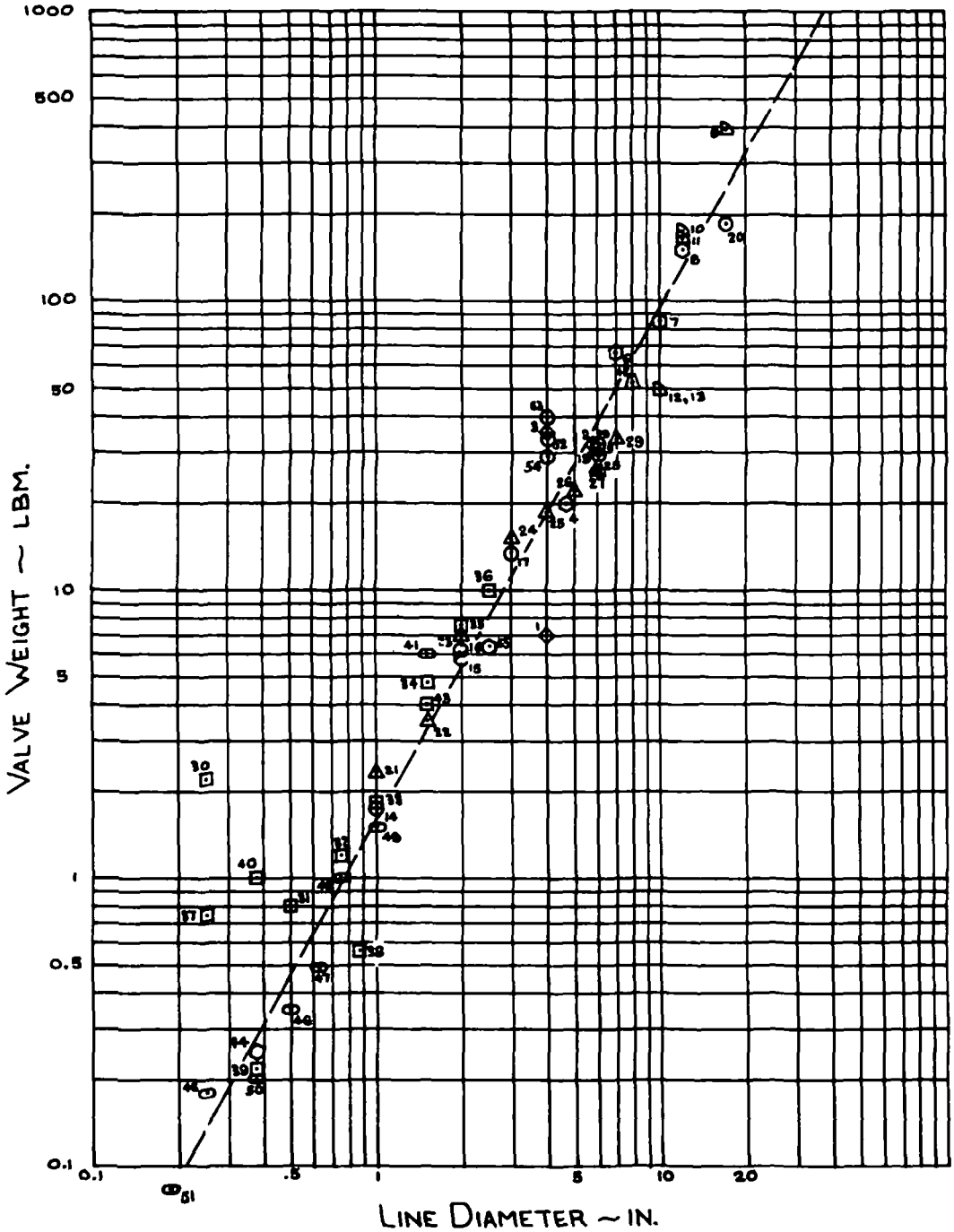
		WT. – LB
SUMP – EACH		(109.25)
18 IN. I.D. WELD FLANGE	=	10.00
18 IN. I.D. DUAL CONOSEAL FLANGE = 16.5/2	=	8.25
SCREENS		
A = 1.2*.38*π*162*.75*.101 = 17.6	=	17.60
B = 5.9*.10*π*159*.75*.101 = 22.4	=	22.40
C = 7.5*152.*π*.004 LB/IN^2 = 14.35	=	14.35
D = SAME AS B	=	22.40
MISC. (RNDM)	=	14.25
TOTAL FOR (2) LOX ANTI-VORTEX & SUMP	=	218.50

NOTE:
- SUMP WEIGHTS ARE BASED ON LAYOUT CALCULATIONS

CRYOGENIC VALVE WEIGHTS

TYPE OF VALVE

○ BALL VALVE	△ BUTTERFLY
□ SOLENOID	⬡ RELIEF
△ BLADE	◇ FILL AND DRAIN
⬭ CHECK	⏢ PREVALVE



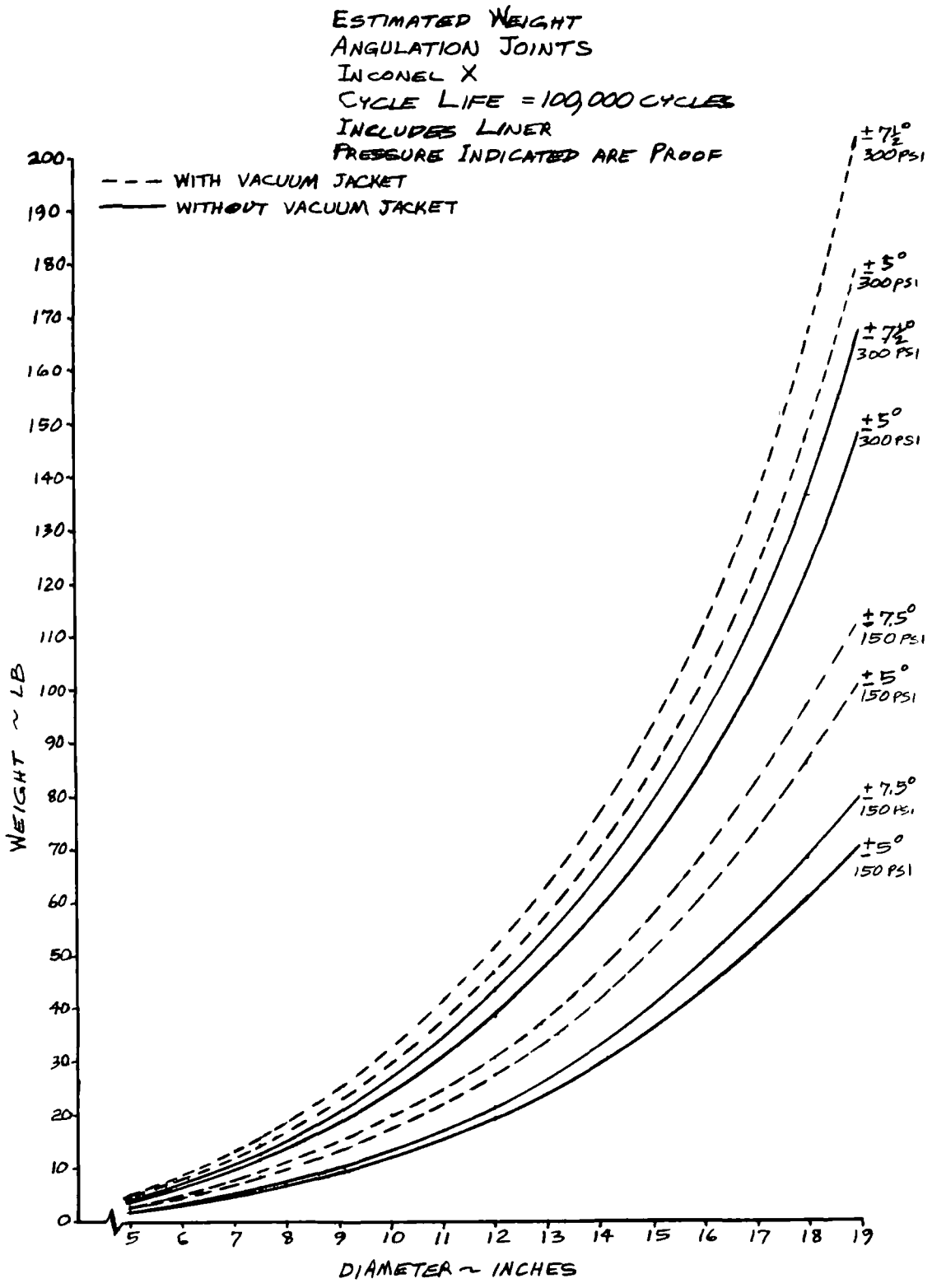
CRYOGENIC VALVE SUMMARY

No.	Type of Valve	Line Dia (in)	Valve Wt (lb)	Mfr.	Use
1	Fill and Drain	4	7	Fairchild	S-IV E
2	"	5.75	32	Parker	S-IC
3	"	4	35	Convair	Centaur
4	Vent and Relief	4.625	20	Ametek/Calmec	S-IV E
5	"	6	31	"	"
6	"	7	66.5	"	S-II
7	"	10	85	Whittaker	S-IC
8	"	12	150	"	"
9	Prevalve	17	395	"	"
10	"	12	175	"	
11	"	12	165	"	
12	"	10	50	Snaptite/Aervalve	S-IV E
13	"	10	50	"	
14	Ball	1.00	1.73	Parker	
15	"	2.00	5.80	"	
16	"	2.00	6.20	"	
17	"	3.00	13.4	"	
18	"	6.00	30.0	"	
19	"	6.00	32.0	"	
20	"	17.00	185.		S-IC
21	Blade	1.00	2.30	Futurecraft	
22	"	1.50	3.50	"	
23	"	2.00	7.00	"	
24	"	3.00	10.5	"	
25	"	4.00	18.6	"	
26	"	5.00	22.0	"	
27	"	6.00	26.0	"	
28	"	6.00	26.8	"	
29	"	7.00	33.2	"	
30	Solenoid	.250	2.20	Valcor	
31	"	.500	.800	"	
32	"	.750	1.20	"	
33	"	1.00	1.80	"	
34	"	1.50	4.75	"	
35	"	2.00	7.55	"	
36	"	2.50	10.0	"	

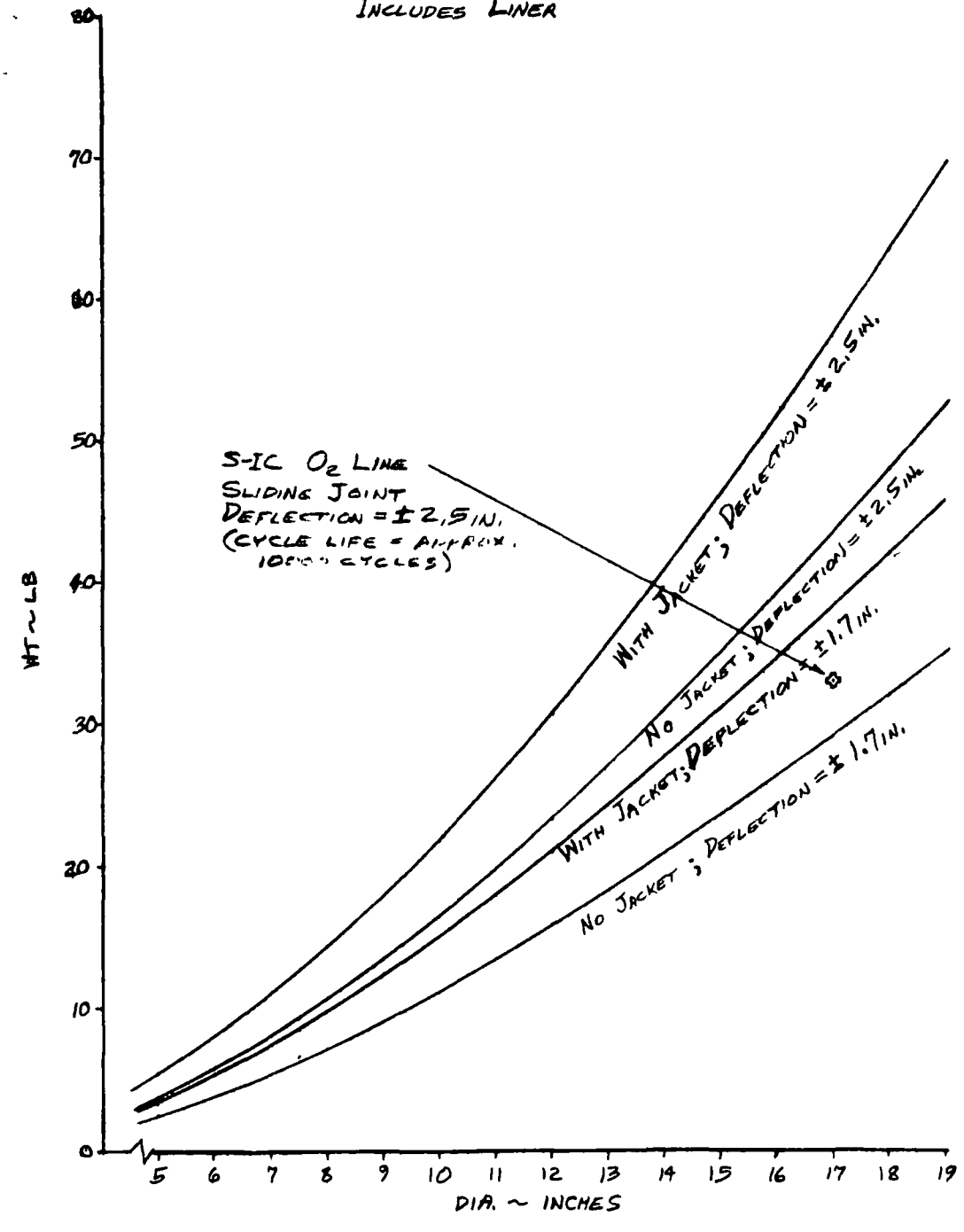
No.	Type of Valve	Line Dia (in)	Valve Wt (lb)	Mfr.
37	Solenoid	.250	.750	Wright
38	"	.875	.560	"
39	"	.375	.218	"
40	"	.375	1.00	NAR
41	Check	1.50	6.00	"
42	Buttertly	8.00	52.0	"
43	Solenoid	1.50	4.0	"
44	Relief	.375	.250	"
45	Check	.250	.180	Circle Seal
46	"	.500	.350	"
47	"	.625	.490	"
48	"	.750	1.000	"
49	"	1.000	1.500	"
50	"	.375	.200	"
51	"	.1825	.08	"
52	Ball	4	34	
53	"	4	40	
54	"	4	29	
55	Vent and Relief	2.5	6.4	

PAGES 2.6-18 THRU 2.6-23 CONTAIN:

- ESTIMATED WEIGHT CURVES FOR SLIDING JOINTS AND ANGULATION JOINTS.
- THE METHOD OF ANALYSIS USED TO DERIVE THE ESTIMATED WEIGHT CURVES.
- AN ESTIMATED WEIGHT VS. ACTUAL WEIGHT PLOT OF HARDWARE DATA USED TO SUBSTANTIATE THE ACCURACY OF THE METHOD OF ANALYSIS USED TO DERIVE THE ESTIMATED WEIGHT CURVES.


ESTIMATED WEIGHT
ANGULATION JOINTS
INCONEL X
CYCLE LIFE = 100,000 CYCLES
INCLUDES LINER
PRESSURE INDICATED ARE PROOF
--- WITH VACUUM JACKET
——— WITHOUT VACUUM JACKET
WEIGHT ~ LB
DIAMETER ~ INCHES
±7½° 300PSI
±5° 300PSI
±7½° 300 PSI
±5° 300PSI
±7.5° 150 PSI
±5° 150PSI
±7.5° 150 PSI
±5° 150 PSI

ESTIMATED WEIGHT
SLIDING JOINTS
300 PSI PROOF PRESSURE
INCONEL X
CYCLE LIFE = 100,000 CYCLES
INCLUDES LINER



INPUT DATA

SUPPLY ALL OF THE FOLLOWING DATA.

PRESS
DLINE
ALPHA OR DEF (THE ONE NOT USED = 0.)
H
DH
FTY
RHØ
E
LNR
JAC
TYPE

SUPPLY ONE OF THE FOLLOWING LISTS AND SET ITEMS IN THE OTHER EQUAL TO 0.

NPLY		NCØN
LBLØS	OR	LCØN
TPLY		

WHERE:

PRESS = PROOF PRESSURE ~ PSI
DLINE = LINE DIAMETER ~ IN.
ALPHA = ANGULAR DEFLECTION ~ DEG. (½ TOT - DEF)
DEF = LINEAR DEFLECTION ~ IN. (½ TOTAL TRAVEL)
H = BELLOWS OUTSIDE RADIUS LESS INSIDE RADIUS ~ IN.
DH = DELTA RADIUS (BELLOWS ID LESS DLINE) ÷ 2
FTY = LIMIT BULGING STRESS ~ PSI
RHØ = DENSITY OF BELLOWS MATL. ~ LB/IN³
E = MODULUS OF ELASTICITY ~ PSI
LNR = INDICATOR; 1. IF LINER IS USED; 0. IF NO LINER
JAC = INDICATOR; 1. IF VAC. JACKETED; 0. IF NO VAC JACKET
TYPE = BELLOWS TYPE FACTOR

BRADED	1.00
ANGULATION JOINT – GIMBAL	2.10
– U JOINT (PAIR)	2.10
– U JOINT (SINGLE)	1.65
SLIDING JOINT	1.10

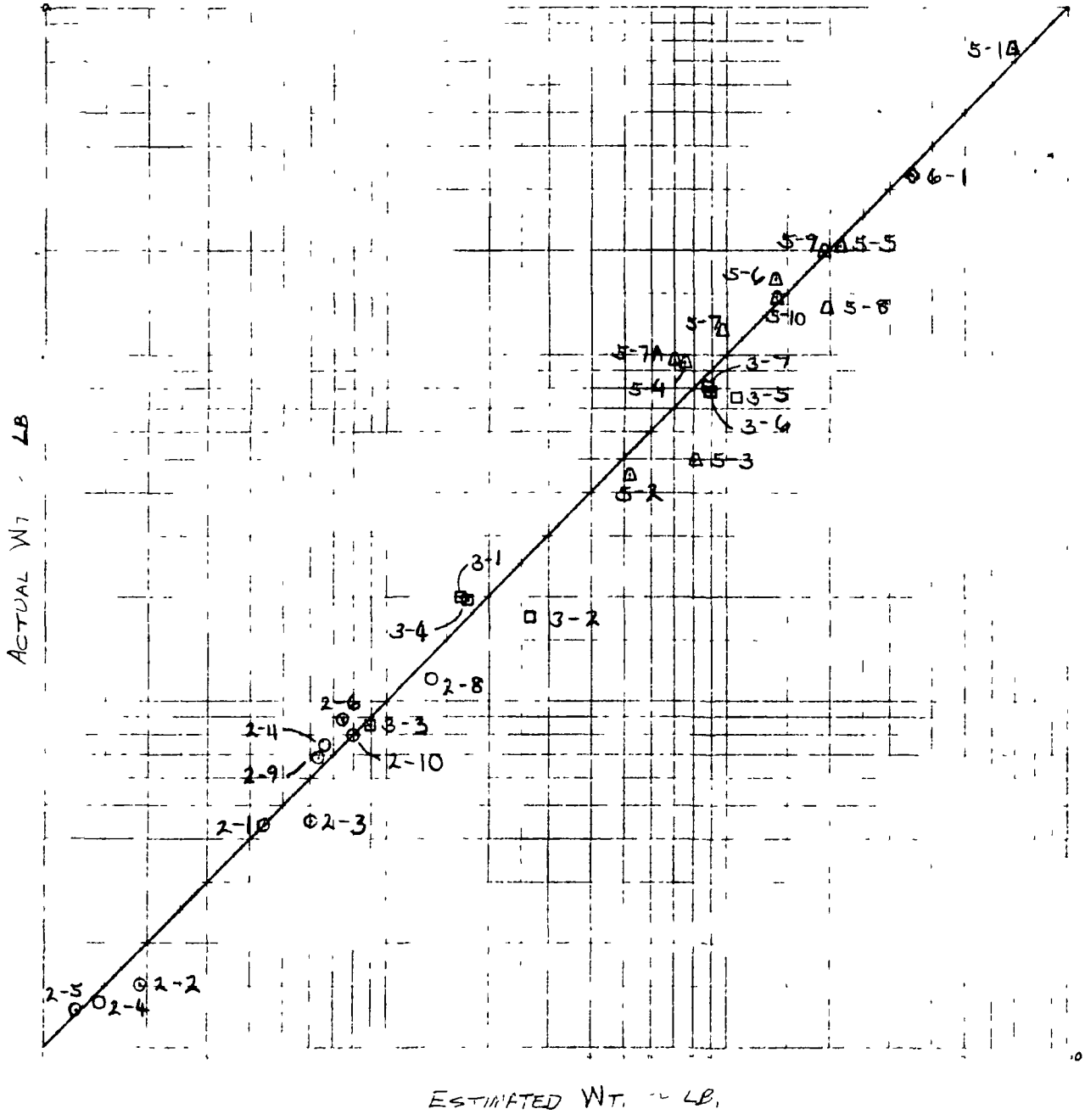
NPLY = NO. OF PLYS
LBLØ = LENGTH OF BELLOWS
TPLY = THICKNESS OF EACH PLY

NCØN = NO. OF CONVOLUTIONS
LCØN = LENGTH OF ONE CONVOLUTION

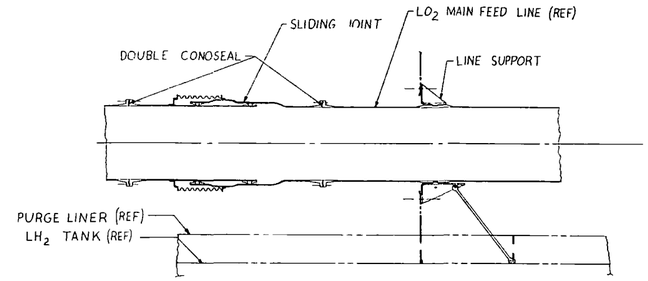
SOURCE PROGRAM

```
 EDIT BELLOWS
*TY0-100
    1.000 C      THIS PROGRAM COMPUTES THEORITICAL BELLOWS WEIGHT
    1.100        REAL NPLY,NCON,LCON,LBLOS,MOTN,LNR,JAC
    2.000        NAMELIST
    3.000       1PRESS,NPLY,FTY,ALPHA,NCON,H,DEF,LCON,LBLOS,DLINE,
    4.000       2DH,TPLY,RHO,E,TYPE,LNR,JAC
    4.500        CALL EOFSET(998S)
    5.000 1      INPUT(105)
    6.000        D=DLINE+DH+H
    6.100        DEF1=DEF
    7.000        IF(DEF.GT.0.) GO TO 10
    8.000        THETA=ALPHA/57.29858
    9.000        DEF1=D/2.*SIN(THETA)
   10.000 10     IF(NPLY.EQ.0.) GO TO 100
   10.100        GO TO 30
   10.200 20     H=H-.01
   11.000 30     LCON=2.*H/3.63
   12.000        NCON=LBLOS/LCON
   12.500        IF(ALPHA.GT.0.) NCON=(LBLOS-2.-.4*DLINE)/LCON
   13.000        TEFF=NPLY*TPLY*(.57+2.*H/LCON)
   14.000        WBLOS=RHO*3.1416*D*TEFF*LBLOS
   15.000        MOTN=41.4E6*TPLY*DEF1/(NCON*H**2)
   15.100        BULG=(PRESS/(2.*NPLY))*(H/TPLY)**2
   16.000        HOOP=PRESS*D*.5/TEFF
   16.100        IF(BULG.GT.FTY) GO TO 20
   17.000        OUTPUT(108) WBLOS,MOTN,BULG,HOOP
   18.000        GO TO 200
   19.000 100    J=0
   19.100 101    J=J+1
   20.000        NPLY=J
   21.000        TBLG=H*(PRESS/(2.*NPLY*FTY))**.5
   22.000        TBLG=.001*INT(TBLG*1000.+.5)
   23.000        TMTN=(FTY*NCON*H**2)/(DEF1*41.4E6)
   24.000        TMTN=.001*INT(TMTN*1000.+.5)
   25.000        IF(TBLG.GT.TMTN) GO TO 101
   25.100        TPLY=TBLG
   26.000        LBLOS=NCON*LCON
   26.500        IF(ALPHA.GT.0.) LBLOS=NCON*LCON+2.+.4*DLINE
   27.000        TEFF=NPLY*TPLY*(.57+2.*H/LCON)
   28.000        WBLOS=RHO*3.1416*D*TEFF*LBLOS
   29.000        HOOP=PRESS*D*.5/TEFF
   30.000 120    OUTPUT(108) WBLOS,NPLY,TEFF,TPLY,LBLOS,HOOP
   30.500        NPLY=0.
   31.000 200    TLINE=PRESS*DLINE*.5/FTY
   32.000        WLINER=3.1416*DLINE*TLINE*LBLOS*RHO*2.
   33.000        WREST=(RHO*LBLOS*PRESS*.785*(DLINE+2.*DH+2.*H)**2/FTY)*3
 .
   33.100        TJAC=((15.*(DLINE+2.*DH+2.*H+1.)**3*(1-.33**2))
   33.110       1/(2.*E))**(1./3.)
   33.120        WJAC=3.1416*(DLINE+2.*DH+2.*H+1.)*RHO*TJAC*LBLOS/1.5
   33.150        WTOT=(WBLOS+WREST)*TYPE+WLINER*LNR+WJAC*JAC
   34.000        OUTPUT(108) TLINE,WLINER,WREST,TJAC,WJAC,WTOT
   34.400        GO TO 1
   34.500 998    GO TO 999
   35.000 999    STOP
   36.000        END
--EOF HIT
*
```

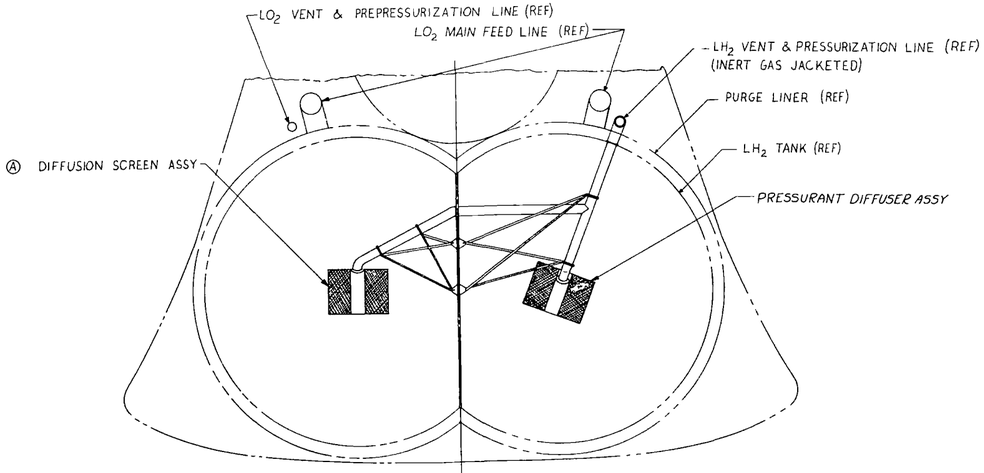
BELLOWS ESTIMATED WT VS. ACTUAL WT.



		Est	Act	Type	Line Dia. IN.	Pressure PSI	Liner?	Vac. Jkt.?	Line Defl IN.
2-1	Bellows	.44	.44	Braided	1.44	938	No	No	.8
2-2	"	.19	.15	"	.75	90	"	"	.98
2-3	"	.60	.45	"	1.00	250	"	"	1.6
2-4	"	.145	.135	"	"	60	"	"	.8
2-5	"	.125	.127	"	"	"	"	"	.7
2-6	"	.74	.90	"	2.00	400	"	"	1.0
2-8	"	1.36	1.15	"	2.50	"	"	"	1.2
2-9	"	.63	.70	"	"	120	"	"	.92
2-10	"	.80	.80	"	"	"	"	"	1.2
2-11	"	.66	.75	"	"	"	"	"	.95
3-1	"	1.66	2.00	Gimbal	1.12	4400	"	"	Angle def'n 10.
3-2	"	2.65	1.75	"	2.00	450	"	"	15.
3-3	"	.89	.85	"	1.75	375	Yes	"	7.
3-4	"	1.72	1.97	"	3.00	508	"	"	"
3-5	"	10.62	7.56	"	4.50	700	"	"	6.
3-6	"	8.97	7.81	"	"	"	"	"	8.5
3-7	"	8.74	7.91	"	"	"	"	"	"
5-1	"	68.04	76.1	U-Joint (ball)	8.00	1670	No	No	6.
5-2	"	5.18	4.47	"	5.00	308	"	"	5.
5-3	"	8.14	4.97	"	"	612	"	"	"
5-4	"	7.48	9.48	"	8.00	147	"	"	7.
5-5	"	21.69	20.54	"	"	140	"	Yes	7.5
5-6	"	13.89	16.56	"	"	147	"	"	5.
5-7	"	9.68	11.75	"	"	248	"	No	7.
5-7A	"	6.95	9.64	U-Joint (slider)	"	"	"	"	"
5-8	"	19.63	13.7	" (ball)	"	"	Yes	"	"
5-9	"	19.19	19.93	U-Joint (ball)	10.00	147	No	Yes	5.
5-10	"	13.80	14.72	"	"	"	"	No	"
6-1	"	34.56	33.00	Sliding Joint	17.00	300	"	"	(±2.5 IN)

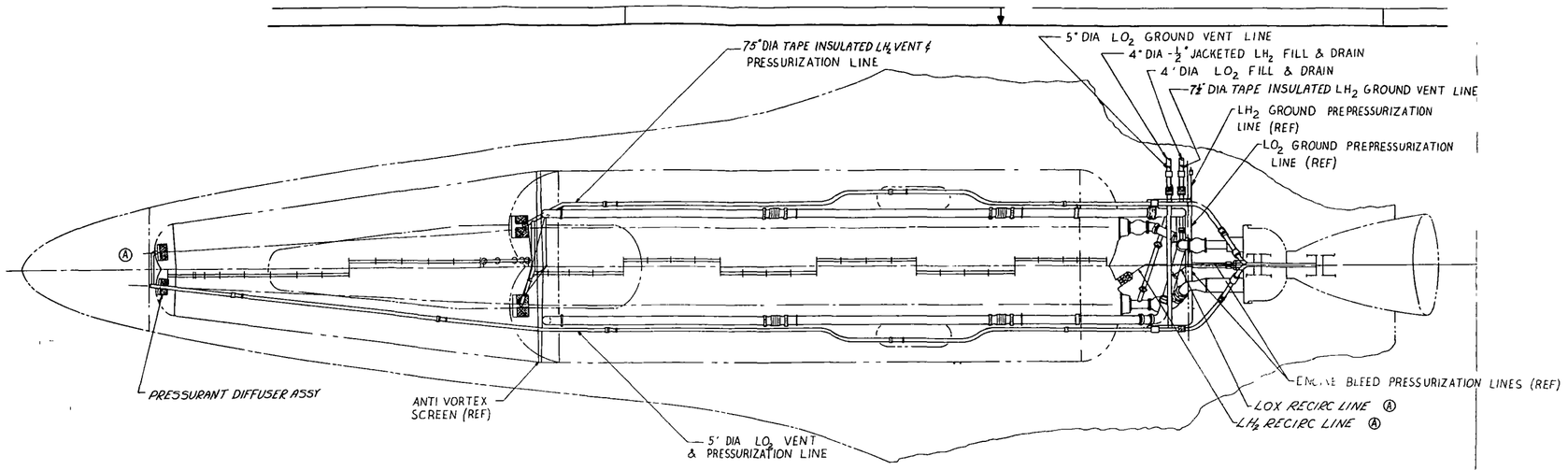


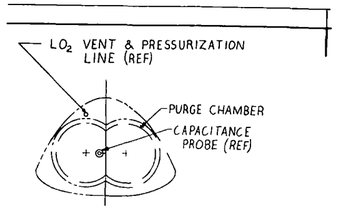
E Ⓐ
SCALE 1/8


LO_2 VENT & PREPRESSURIZATION LINE (REF)
LO_2 MAIN FEED LINE (REF)
LH_2 VENT & PRESSURIZATION LINE (REF)
(INERT GAS JACKETED)
PURGE LINER (REF)
Ⓐ DIFFUSION SCREEN ASSY
LH_2 TANK (REF)
PRESSURANT DIFFUSER ASSY

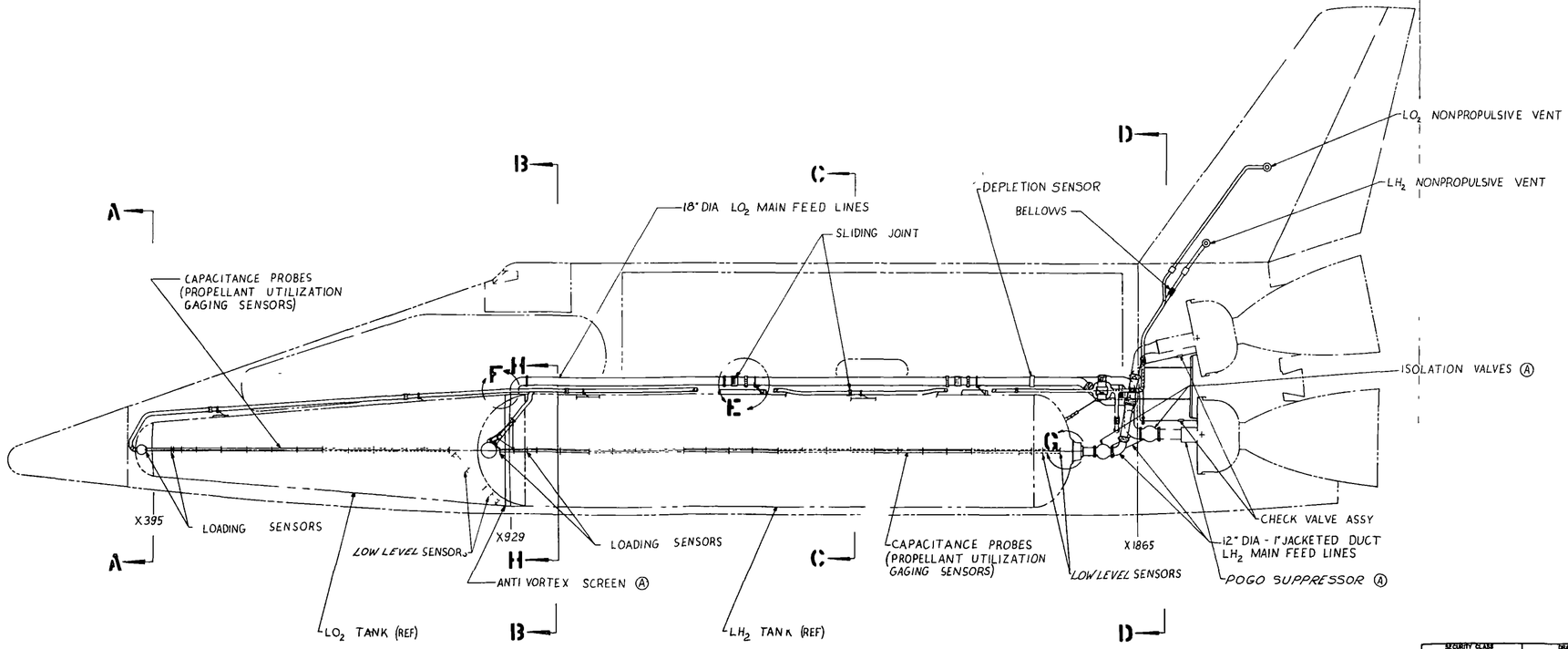
H-H
SCALE 1/20

SECURITY CLASS	DRAWING NUMBER	REV	SH
U	255BJ50069	A	

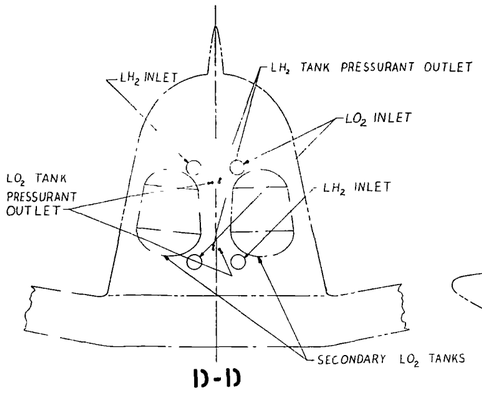

7.5" DIA TAPE INSULATED LH2 VENT & PRESSURIZATION LINE
5" DIA LO2 GROUND VENT LINE
4" DIA - 1/2" JACKETED LH2 FILL & DRAIN
4" DIA LO2 FILL & DRAIN
7.5" DIA TAPE INSULATED LH2 GROUND VENT LINE
LH2 GROUND PREPRESSURIZATION LINE (REF)
LO2 GROUND PREPRESSURIZATION LINE (REF)
PRESSURANT DIFFUSER ASSY
ANTI VORTEX SCREEN (REF)
5" DIA LO2 VENT & PRESSURIZATION LINE
ENGINE BLEED PRESSURIZATION LINES (REF)
LOX RECIRC LINE Ⓐ
LH2 RECIRC LINE Ⓐ



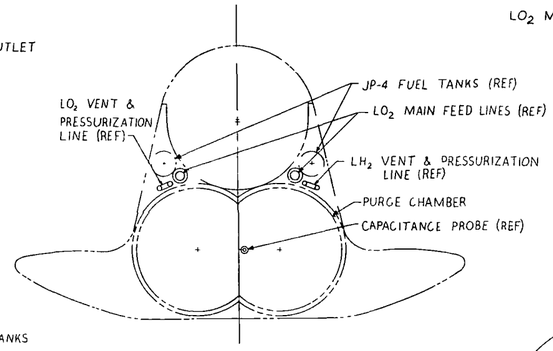
A - A



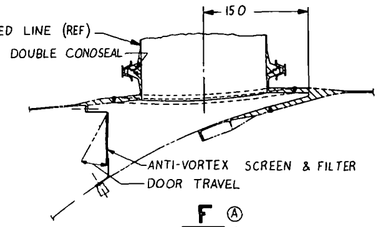
SECURITY CLASS	DRAWING NUMBER	REV	SH
U	255BJ50069	A	



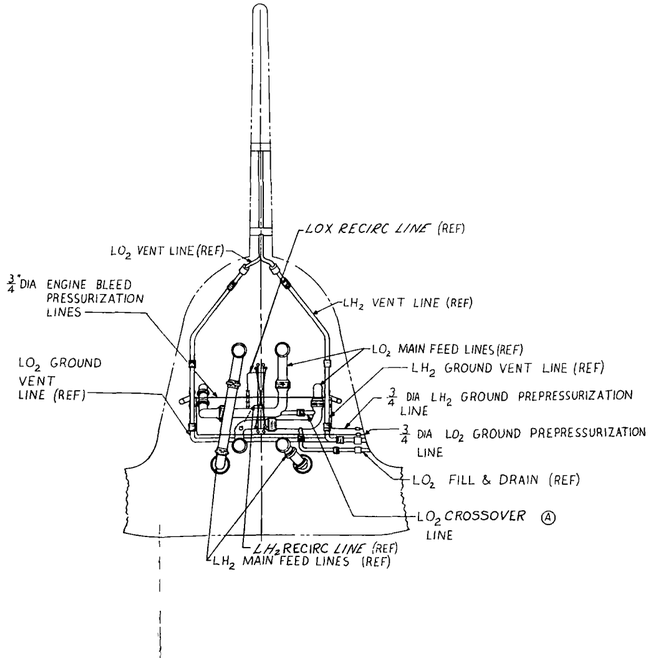
D-D

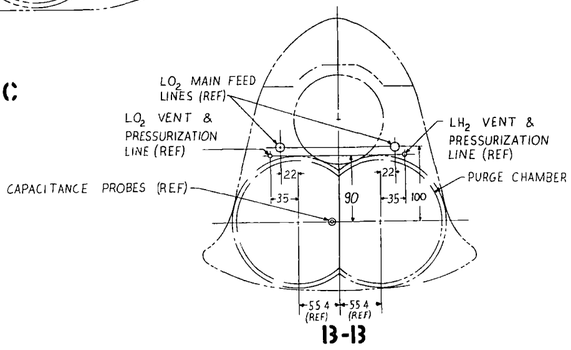

LO2 VENT & PRESSURIZATION LINE (REF)
JP-4 FUEL TANKS (REF)
LO2 MAIN FEED LINES (REF)
LH2 VENT & PRESSURIZATION LINE (REF)
PURGE CHAMBER
CAPACITANCE PROBE (REF)

C-C

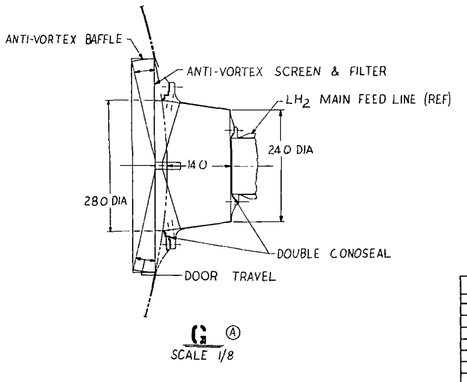


F Ⓐ
SCALE 3/16


LOX RECIRC LINE (REF)
LO2 VENT LINE (REF)
¾ DIA ENGINE BLEED PRESSURIZATION LINES
LH2 VENT LINE (REF)
LO2 MAIN FEED LINES (REF)
LO2 GROUND VENT LINE (REF)
LH2 GROUND VENT LINE (REF)
¾ DIA LH2 GROUND PREPRESSURIZATION LINE
¾ DIA LO2 GROUND PREPRESSURIZATION LINE
LO2 FILL & DRAIN (REF)
LO2 CROSSOVER Ⓐ LINE
LH2 RECIRC LINE (REF)
LH2 MAIN FEED LINES (REF)



B-B



G Ⓐ
SCALE 1/8

ZONE	LTR	REVISIONS DESCRIPTION	DATE	APPROVED
	A	CHANGED LH_2 DIFFUSION ASSY VIEW H H LO_2 DIFFUSION ASSY PLAN VIEW VIEW E LO_2 ANTI VORTEX ASSY-VIEW F LH_2 SUMP ASSY - VIEW G ADDED LH_2 RECIRCULATION LINES LO_2 RECIRCULATION LINES POGO SUPPRESSOR RELOCATED LH_2 ISOLATION VALVES LO_2 CROSSOVER LINE	5-21 71	

QTY REQD	QTY REQD FIND NO	CODE IDENT NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO	NOTE NO	ZONE
				PARTS LIST					

LOFT DATA	CHKD JAMES EARL DAVIS	5/11/71	MCDONNELL AIRCRAFT COMPANY SAINT LOUIS MISSOURI
LAYOUT NO	STR	5/11/71	MCDONNELL DOUGLAS CORPORATION
TOLERANCE UNLESS NOTED .XX = ±.03 .XXX = ±.010	PROJ D. F. STONE	5/11/71	MAIN PROPULSION SYSTEM INSTALLATION - DELTA WING ORBITER
FINISH SPEC	CONTR NO		SIZE J CODE IDENT NO 76301 255BJ50069
DASH NO	FIN ART	NEXT ASSY	USED ON	QTY REQD	APPLICATION	SCALE 1/50 & NOTED	WT	LB	SHEET 1

2.7 Propulsion - Cruise Back	574	
		Page No.
Engine & Accessories	(11282)*	2.7-3
Engine	10660	
Ignition and Control	30	
Lubrication System (Dry)	95	
Accessories	497	
Installation, Ducts, Shroud	(2962)*	2.7-4
Air Induction	62	
Engine Mounting	439	
Nacelles/Pylons	1567	
Deployment Provisions	894	
Propellant System	(338)	2.7-7
Fill/Drain	57	2.7-6
Pressurization (Dry)	13	2.7-6
Vent System	10	2.7-6
Feed System	163	2.7-7
Transfer System	47	2.7-6
Supports/Installation	48	2.7-7
Tankage	(175)	2.7-8
Tanks	79	
Insulation	44	
Supports	52	
Contingency	(516)	2.7-2
Increment for Resupply	455*	
Easterly and Polar	61	

*Not included in Easterly or Polar Missions.

Section 2.7

The cruise propulsion system weight was calculated using drawings numbered 255BJ50147 and 255BJ50070 Rev. A and the ABES Schematic (page 2.7-5). Weight was included for couplings, supports, wiring and installation parts where experience indicates these items will be required.

A contingency was added to the total system weight to provide for items which may have been overlooked. Experience indicates, as shown in section 1, that a contingency allowance is needed at this stage of design maturity to assure a 50% probability that the weight will not be exceeded.

Fuel system and tanks are not removable for the easterly and polar missions.

Easterly/Polar Cruise System Weight

Propellant System	383 lb
Tankage	175 lb
Contingency	61 lb
Total	574 lb

The following notes apply to this section:

- The engine weight is based on a quote from General Electric for a version of one of their engines taylored to Shuttle requirements.
- Accessory and fire detection and control weights are based on small extrapolations from current aircraft systems.
- Installation, duct and shroud weights were derived empirically. This derivation is shown on page 2.7-13. The empirical correlations are shown on pages 2.7-9 thru 2.7-12.
- Deployment actuator weights were verified using the method described in section 2.12.

CRUISE PROPULSION SUMMARY

7 PROPULSION – CRUISE BACK					15273
ENGINE & ACCESSORIES				11282	
ENGINE			10660		
IGNITION AND CONTROL SY			30		
LUBRICATION SY (DRY)			95		
ACCESSORIES			497		
INSTALLATION, DUCTS, SHROUD				2962	
AIR INDUCTION			62		
ENGINE MOUNTING			439		
NACELLES PYLONS (INCL 894 LB MECH)			2461		
PROPELLANT SY				338	
FILL/DRAIN			57		
PRESSURIZATION (DRY)			13		
VENT SY			10		
PUMP			N/A		
FEED SY			163		
TRANSFER SY			47		
DUMP SY			N/A		
SUPPORTS/INSTALLATION			48		
TANKAGE – NON INTEGRAL	TANK	INSULATE	SUPTS		175
FUEL	79	44	52		
CONTINGENCY					516

DESIGN DATA SUMMARY

7 PROPULSION – CRUISEBACK	
NO OF ENGINES	4
ENGINE THRUST – S L STATIC – LB	CLASSIFIED
SPECIFIC FUEL CONSUMPTION LB/LB – THRUST PER HR @ NOMINAL CRUISE ALTITUDE – FT	CLASSIFIED
NOMINAL CRUISE ALTITUDE – FT	N/A
NOMINAL CRUISE SPEED – KNOTS	N/A
CRUISE ALTITUDE ENGINE OUT – FT	N/A
CRUISE SPEED, ENGINE OUT – KNOTS	N/A
CRUISE RANGE (ACTUAL REQ) – NA MI	N/A
CRUISE RANGE (MAX AVAIL – NO HEADWIND, ALL ENGINES UP)	N/A
CRUISE LIFT DRAG RATIO	N/A
ENGINE THRUST SIZED BY	APPROACH GO/AROUND ABORT
LIFT COEFFICIENT FOR CRITICAL THRUST CONDITION	.26
LIFT DRAG RATIO FOR CRITICAL CONDITION	6.5

	TYPE	TANK VOL CU FT	TANK MATL	TANK PRES-PSI	BURST FACTOR	NO OF TANKS
FUEL SYSTEM	JP	80	AL	30	2	2
PRESSURIZATION SYSTEM	HELIUM	MAIN ACCENT PNEUMATIC SYS				

AIR INTAKE – LENGTH–FT	2.3
– DIAMETER–FT	3.8
NACELLE WETTED AREA – EACH–SQ FT	131

NOTE: SEE DWG. NO. 255 BJ 50147 (PAGE 2.7–14)

PROPULSION – CRUISE BACK
ENGINE & ACCESSORIES

			WT. ~LB
ENGINES (4) @ 2665. LB. EA. (P101/F12B)			10660.
IGNITION & CONTROL			(30.)
THROTTLES ETC. ARE INCLUDED IN DISPLAYS & CONTROLS			
IGNITORS ARE INCLUDED IN ENGINE WEIGHT			
WIRING & MISC.			30.
LUBRICATION SYSTEM			(95)
HEAT EXCHANGERS	(INCLUDED IN ENGINE WT)		—
ACCUMULATORS		(4) @ 15. LB	60.
LINES VALVES & MISC.			35.
ENGINE ACCESSORIES			(390.)
BLEED AIR PROVISIONS		(4) @ 10. LB	40.
INSTRUMENTATION			70.
STARTERS (INCL. CARTRIDGES)		(4) @ 70. LB	280.
FIRE DETECTION & CONTROL			(107.)
FIRE EXTINGUISHERS			
BOTTLE		(8) @ 4.5	36.
FLUIDS		(8) @ 5.5	44.
VALVE		(8) @ .5	4.
SENSOR SYSTEMS		(4) @ 2.0	8.
DISTRIBUTION LINES	3/4 IN. .016 Ti	840 IN. @ .006 LB/IN	5.
WIRING & MISC.			10.
TOTAL ENGINE AND ACCESSORIES			11282

NOTES:

- ENGINE WEIGHT IS BASED ON A GENERAL ELECTRIC QUOTE AND INCLUDES TAIL PIPE, OIL COOLER AND BLADE CONTAINMENT.

INSTALLATION, DUCTS, SHROUDS

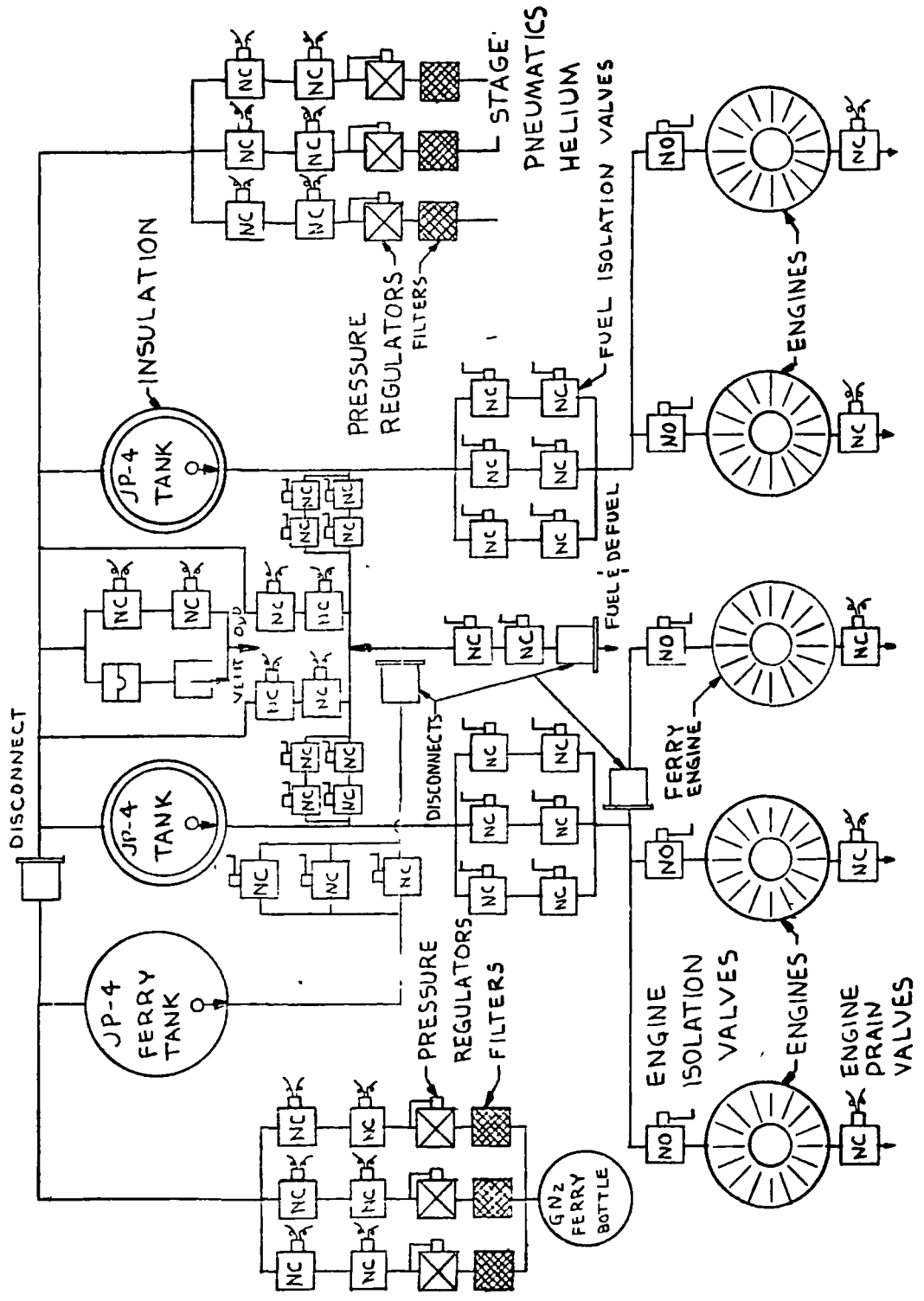
		WT. ~ LB
AIR INDUCTION		(62.)
ENGINE MOUNTING		(439.)
FROM CORRELATION		239.
SPECIAL INCREMENT FOR 180° YOKE		200.
NACELLES & PYLONS		(1567.)
NACELLE SHELL & CAVITY		853.
PYLON & PROVISIONS		714.
DEPLOYMENT PROVISIONS		(894.)
ENGINE ACTUATORS	(4) @ 45.	180.
DOOR ACTUATORS	(4) @ 92.	368.
FLIPPER DOOR ACTUATORS	(4) @ 16.5	66.
LOCKING AND LATCHING MECH		
PYLONS PRELIM. LAYOUT	(4) @ 40.0	160.
DOORS "	(4) @ 25.0	100.
FLIPPER DOORS "	(4) @ 5.0	20.
TOTAL INSTALLATION, DUCTS, SHROUDS		2962

NOTES:

- FOR AIR INDUCTION, ENGINE MOUNTS AND NACELLE AND PYLON CORRELATIONS AND DERIVATION SEE PAGES 2.7-9 THRU 2.7-13

- FOR ACTUATOR ESTIMATION METHOD SEE SECTION 2.12

AIRBREATHING PROPULSION SYSTEM SCHEMATIC



PROPULSION – CRUISE BACK

PROPELLANT SYSTEM

PAGE 1 OF 2

	LINE DIA-IN.	QTY	UNIT WT-LB	WT-LB
FILL & DRAIN				(56.3)
DISCONNECT – GROUND	2.13	(1) @	6.0	6.0
N.C. PNEUMATIC (W. IND)	2.13	(2) @	6.0	6.0
DISCONNECT – FERRY PROV.	2.13	(1) @	6.0	6.0
LINES .028 AL	2.13	420 IN @	.0186 LB/IN	7.8
JACKET .028 AL	2.50	420 IN @	.0217 LB/IN	9.1
COUPLINGS AL	2.13	(12) @	.310	3.7
COUPLINGS AL	2.50	(12) @	.367	4.7
TEE ASSY (INTER LINE / OUTER LINE)	2.13 / 2.50	(1) @	2.60	2.6
SLIDING JOINTS JACKETED	2.13	(4) @	2.6	10.4
PRESSURIZATION SYSTEM				(13.3)
FILTERS	.5	(3) @	1.50	4.5
REGULATORS	.5	(3) @	.90	2.7
N.C. SOLENOID VALVES (W. IND)	.5	(6) @	.46	2.6
LINES .028 AL	.5	500 IN. @	.0042 LB/IN	2.1
COUPLINGS AL	.5	(17) @	.046	.8
CROSS	.5	(2) @	.18	.4
TEE	.5	(2) @	.12	.2
VENT SYSTEM				(10.1)
N.C. SOLENOID VALVES (W. IND)	.5	(6) @	.46	2.8
BURST DISC	.5	(1) @	.46	.5
RELIEF VALVE	.5	(1) @	.46	.5
DISCONNECT – FERRY PROV.	.5	(1) @	.46	.5
LINES .028 AL	.5	1050 IN @	.0042 LB/IN	4.4
COUPLINGS AL	.5	(12) @	.046	.6
TEE	.5	(7) @	.12	.8
FUEL CROSSOVER (TRANSFER SYSTEM)				(47.4)
N.C. PNEUMATIC VALVES (W. IND)	1.5	(8) @	3.25	26.0
LINES .028 AL	1.5	200 IN @	.013 LB/IN	2.6
JACKET .028 AL	1.87	200 IN @	.0163 LB/IN	3.3
TEE (INSIDE LINE / OUTSIDE LINE)	1.5 / 1.87	(4) @	1.4	5.6
SLIDING JOINTS-JACKETED	1.5	(4) @	1.5	6.0
COUPLINGS	1.5	(8) @	.225	1.8
COUPLINGS	1.87	(8) @	.265	2.1

NOTE: SEE DWG. NO. 255 BJ50070 (PAGE 2.7-15)

PROPULSION – CRUISE BACK

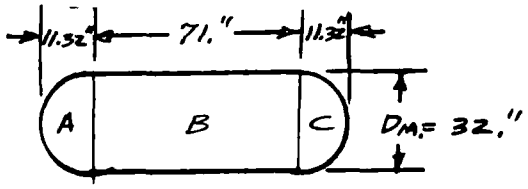
PROPELLANT SYSTEM

	LINE DIA IN.	(QTY)	UNIT WT. LB	WT. LB.
FEED SYSTEM				(162.9)
N.C. PNEUMATIC VALVE (W. IND)	1.5	(12) @	3.25	39.0
N.C. PNEUMATIC VALVE (W. IND.)	1.13	(4) @	2.00	8.0
N.C. SOLENOID VALVE	.5	(4) @	.46	1.8
LINES .028 AL	2.13	300 IN. @	.0186 LB/IN	5.6
JACKETS .028 AL	2.5	300 IN. @	.0217 LB/IN	6.5
LINES .028 AL	1.5	170 IN. @	.013 LB/IN	2.2
JACKETS .028 AL	1.87	170 IN. @	.0163 LB/IN	2.8
LINES .028 AL	1.13	960 IN. @	.0097 LB/IN	9.3
JACKETS .028 AL	1.5	960 IN. @	.013 LB/IN	12.5
SLIDING JOINTS – JACKETED	2.13	(2) @	2.6	5.2
SLIDING JOINTS – JACKETED	1.5	(2) @	1.5	3.0
SLIDING JOINTS – JACKETED	1.13	(8) @	1.3	10.4
FLEX LINES (W. 2 FIRE SHIELDS)	1.13	(4) @	2.06	8.3
COUPLINGS	2.13	(6) @	.31	1.9
COUPLINGS	2.5	(6) @	.367	2.2
COUPLINGS	1.5	(22) @	.225	5.0
COUPLINGS	1.87	(22) @	.265	5.8
COUPLINGS	1.13	(32) @	.112	3.6
COUPLINGS	1.5	(32) @	.225	7.2
COUPLINGS	.5	(4) @	.046	.2
TEE		(4) @	1.150	6.0
CROSS		(4) @	1.60	6.4
TANK FLOAT VALVES		(2) @	5.0	10.0
SUPPORTS & INSTALLATION				(47.5)
FILL & DRAIN				8.4
PRESSURIZATION				2.0
VENT				1.5
FEED				24.4
CROSSOVER				7.1
PNEUMATIC LINES & FTGS				4.1
TOTAL PROPELLANT SYSTEM				337.5

PROPULSION – CRUISE BACK
TANK – JP

WT.~LB.

FUEL TANKS (2 REQUIRED) (175.)



VOL A = $\frac{2}{3}\pi R^2 H$ = 6060 IN.^{3}
VOL B = $\pi R^2 H$ = 56980 IN.^{3}
VOL C = VOL A = 6060 IN.^{3}
TOTAL (1 TK) = 69100 IN.^{3} OR 40 FT.^{3}

(3600 LB / 46.83 LB/FT.^{3} (MIN. DENS. JP) = 77 FT.^{3} + ULLAGE)

AREA, $A = \pi\left[R^2 + \frac{H^2}{2E} \log_e \frac{1+E}{1-E}\right]$; $E = \frac{\sqrt{R^2 - H^2}}{R}$

AREA A = 1310 IN.^{2} ; E = .707
AREA B = πDH = 7140 IN.^{2}
AREA C = AREA A = 1310 IN.^{2}
TOTAL (1 TK) = 9760 IN.^{2} OR 68 FT.^{2}

ULLAGE PRESS = 30 PSI
HEAD PRESS = 8 PSI

$t = \frac{PR}{FTU} = \frac{(38*2)*16}{68000} = .018$ IN.

$\bar{t}$ = .040 ASSUMED; TO INCL. MIN. GAUGE PLUS WELD LANDS AND STIFFENING.

WT. = 9760 IN.^{2} * .040 IN. * .101 LB/IN.^{3} = 39.5 LB EA. 79.
WT. INS. = 20 LAYERS GOLD COATED KAPTON (OVERLAP & SEAMS)
= 20 * 9760 IN.^{2} * 1.12 * .00010 LB/IN.^{2} = 22.0 LB EA. 44.

WT. SUPPORTS = 26. LB/TK. 52.

ENGINE SECTION OR NACELLE GROUP ESTIMATION EQUATIONS

$$\gamma_1 \text{ Engine Section} = \gamma_m + \gamma_t + \gamma_n + \gamma_d + \gamma_c + \gamma_p$$

γ_m (Mounts - Thrust Reaction) $= 7.2\ W_e^{.3}\ T^{.6}\ N_e$

γ_t (Tracks) $= 2.6\ (W_e^{.3}\ L_t\ N_e)^{.8}$

γ_n (Nacelle Shell) $= .315q^{.2}\ N_n\ S_n$

γ_d (Air Induction Provisions) $= .100\ N_n\ L_6\ \left(\frac{C_1 + C_2}{2}\right)^{1.3}\ P_d^{.6}$

γ_c (Cavity Provisions) $= 3.24\ (D_c\ L_7\ N_e/N_n)^{.9}\ N_n$

γ_p (Pylon & Provisions) $= .63q^{.2}\ S_p N_p + 3.\left(\frac{H_p}{\cos\theta\ T_p}\right)^{.25}\ W_n^{.6}\ S_p N_p$

SYMBOLS-ENGINE SECTION OR NACELLE GROUP

C_1 Circumference, Fwd Duct Face - Feet

C_2 Circumference, Aft Duct Face - Feet

D_e Diameter, Engine Compartment - Feet

H_p Height, Pylon (Wing/Fuselage to Nacelle)

L_p Length, Pylon - Feet

L_6 Length, Air Induction Duct - Feet

L_7 Length, Engine Cavity - Feet

L_t Length, Engine Removal Track - Feet

N_e Number, Engines

N_n Number, Nacelles

N_p Number, Pylons

P_d Pressure, Air Intake Duct - PSI

q Pressure, Dynamic (Maximum) - PSF

S_n Wetted Area, Nacelle - Feet ^{2}

S_p Planform Area, Pylon - Feet ^{2}

T Thrust, Maximum Static Sea Level (Uncorrected) -LB./1000

T_p Thickness, Pylon (At Frontal View) - Feet

W_e Weight, Engine - LBS./1000

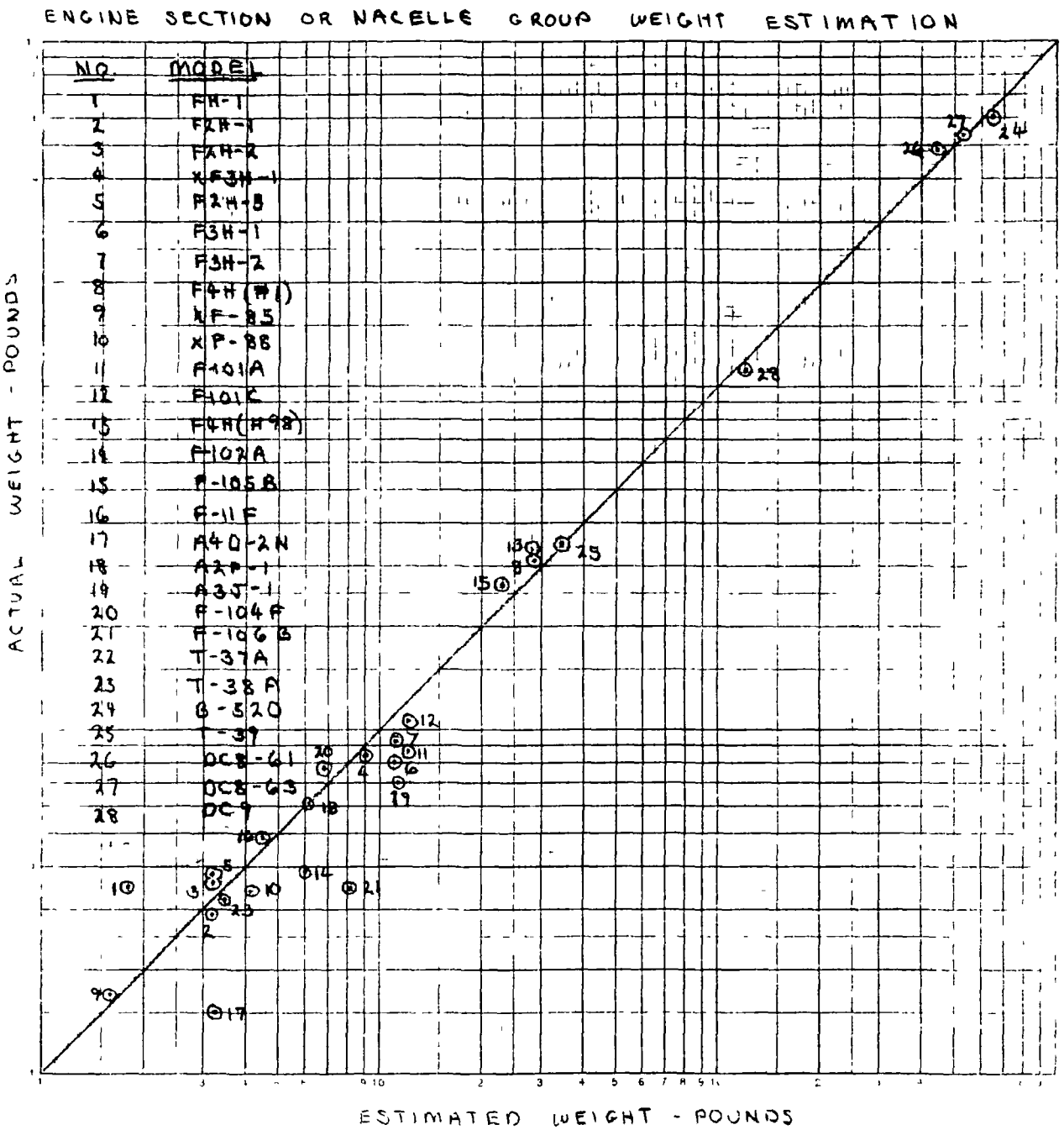
W_h Weight, Engine (s) plus Thrust Reverser(s) Hanging From Pylon-LB./1000

θ Forward Sweep Angle of Pylon at 50% Span

ESTIMATED WEIGHT - ENGINE SECTION OR NACELLE GROUP

ITEM/MODEL	FH-1	F2H-1	F2H-2	XF3H-1	F2H-3	F3H-1	F3H-2	F4H(#1)	XF-85	XF-88	F-101A	F-101C	F4H(#98)	F-102A	F-105B	F-11F
Mounts - Thrust Reaction	18	32	32	45	32	54	58	112	16	41	117	122	112	61	81	45
Tracks				44		48	51	20					20			
Nacelle Shell								154					154		143	
Air Induction Provisions																
Cavity Provisions																
Pylon Provisions																
Total Estimated Weight	18	32	32	89	32	102	109	286	16	41	117	122	286	61	224	45
Actual Weight	35	29	37	83	36	78	93	307	17	34	86	103	315	39	263	48
Unaccountable Weight	17	-3	5	-6	4	-24	-16	21	1	7	-31	-19	29	-22	39	3

ITEM/MODEL	A4D-2N	A2F-1	A3J-1	F-104F	F-106B	T-37A	T-38A	B-52G	DC8-61	DC8-63	DC-9
Mounts - Thrust Reaction	32	62	112	51	82	10	27	460	252	261	100
Tracks				18			8				
Nacelle Shell								2485	1365	1250	457
Air Induction Provisions								64	100	80	23
Cavity Provisions								1062	520	505	255
Pylon Provisions								2599	2330	3250	425
Cavity Pressurization											
Total Estimated Weight	32	62	112	69	82	10	35	6670	4567	5346	1260
Actual Weight	15	61	70	79	39	0	32	5936	4892	5372	1496
Unaccountable Weight	-17	-1	-42	10	-43	-10	3	- 734	325	26	236


ENGINE SECTION OR NACELLE GROUP WEIGHT ESTIMATION
NO. MODEL
1 FH-1
2 FJH-1
3 FJH-2
4 XF3H-1
5 F2H-3
6 F3H-1
7 F3H-2
8 F4H (#1)
9 XF-85
10 XP-86
11 F-101A
12 F-101C
13 F4H(H98)
14 F-102A
15 F-105B
16 F-11F
17 A4D-2N
18 A2F-1
19 A3J-1
20 F-104F
21 F-106B
22 T-37A
23 T-38A
24 G-520
25 T-39
26 DC8-61
27 DC8-63
28 DC9
ACTUAL WEIGHT - POUNDS
ESTIMATED WEIGHT - POUNDS

CRUISE ENG. SYS.
G.E. ENG.

C_1 = 12.3
C_2 = 12.0
D_C = 4.33
H_P = 2.5
L_6 = 2.28
L_7 = 6.0
N_e = 4
N_N = 4
N_p = 4
P_d = 5
q = 690
ℓ_N = 131 FT
S_p = 17.8
T = 20
T_p = 1.083
W_e = 2.9
θ = 0.
W_h = 3.4

MOUNTS = $\gamma_m = 7.2 * 2.9^{.3} * 20.^{.6} * 4. =$ 239.

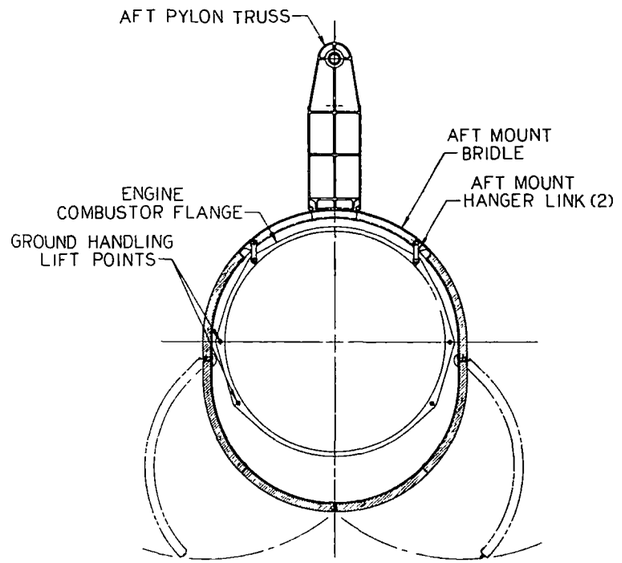
NACELLE SHELL = $\gamma_n = .315 * 690^{.2} * 4. * 131. =$ 610.

AIR IND. PROV. = $\gamma_d = .1 * 4. * 2.28 * 12.15^{1.3} * 5^{.6} =$ 62.

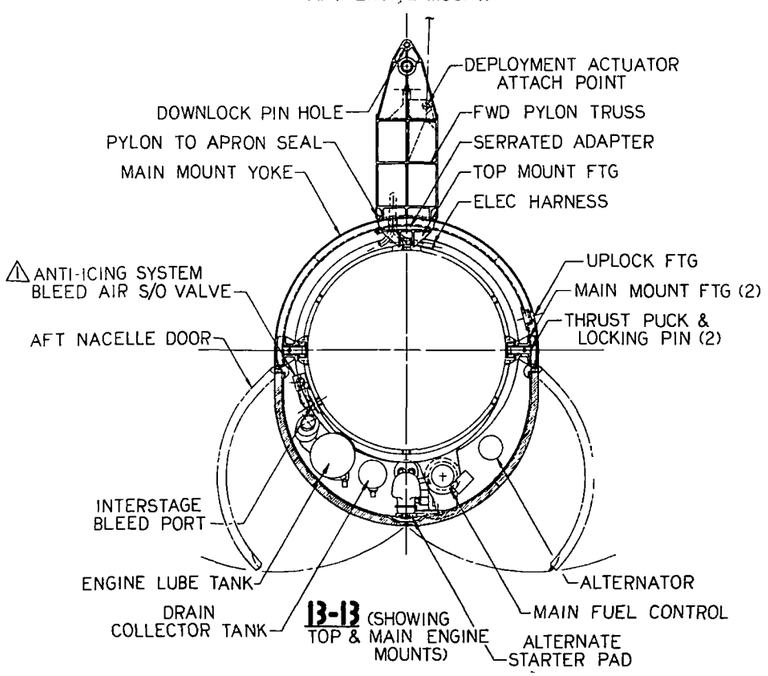
CAVITY PROV. = $\gamma_c = 3.24 * (4.33 * 6. * 4. * / 4.)^{.9} * 4. =$ 243.

PYLON & PROV. = $\gamma_p = .63 * 690^{.2} * 17.8 * 4. + 3. * (2.5/1.083)^{.25} * 3.4^{.6} * 17.8 * 4. =$ 714.

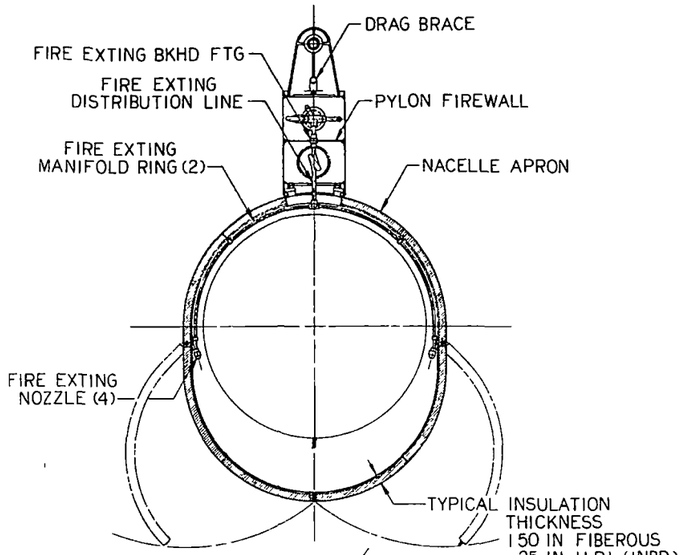
MOUNTS = 239. PLUS 200 LB. FOR SPECIAL DELTA WT. FOR GE's 190° MTG. HARD PTS.



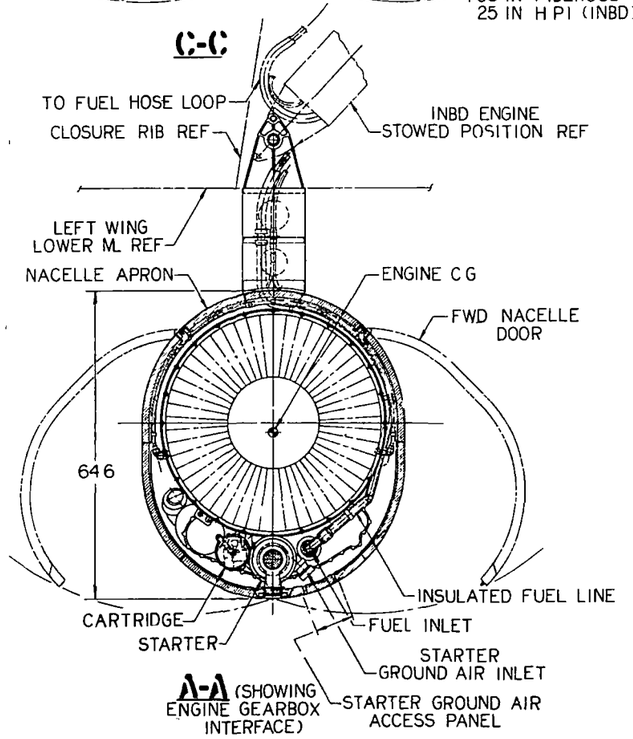
D-D (SHOWING AFT ENGINE MOUNT)



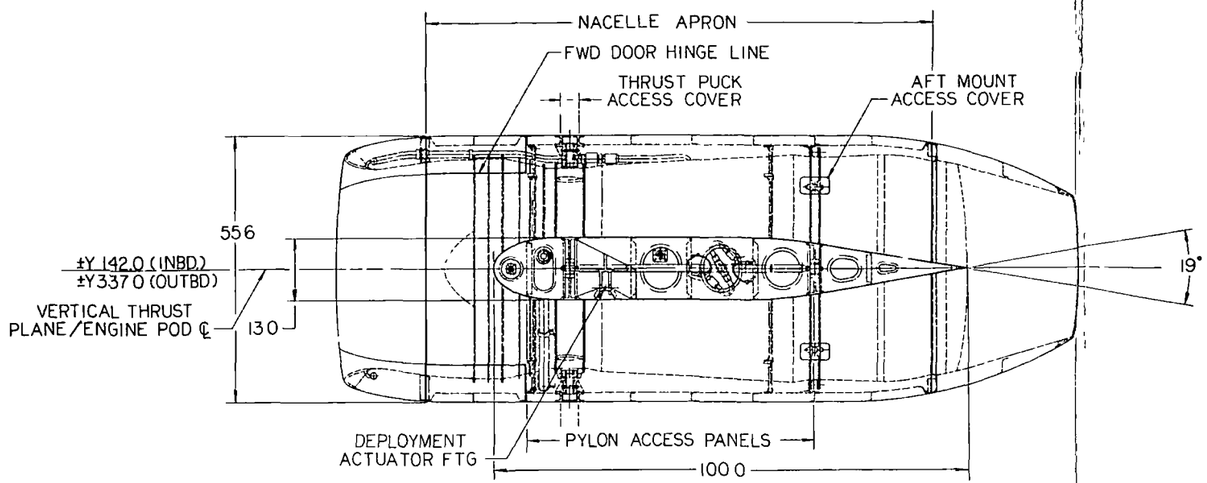
B-B (SHOWING TOP & MAIN ENGINE MOUNTS)

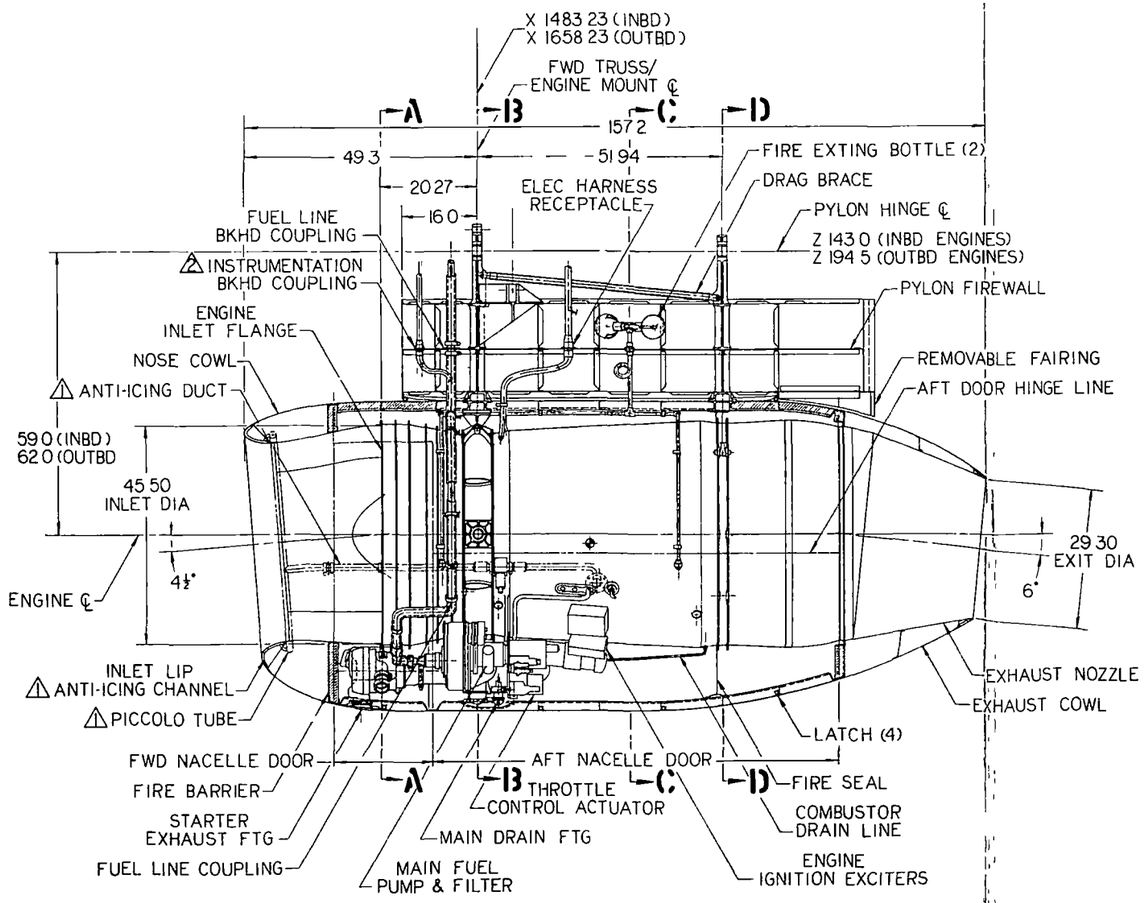


C-C



A-A (SHOWING ENGINE GEARBOX INTERFACE)





4 GE F101/F12B3 ENGINE SHOWN

3 MINIMUM CLEARANCE BETWEEN COWL & ENGINE - 75 IN

⚠2 INSTRUMENTATION BUNDLE INCLUDES FOLLOWING
- ENGINE PRESSURE RATIO
- OIL PRESSURE
- FUEL INLET PRESSURE
- COMPRESSOR DISCHARGE PRESSURE
- FAN PRESSURE RATIO
- TURBINE INLET TEMP
- OIL TEMP
- INLET TOTAL TEMP
- TURBINE BLADE TEMP
- FIRE DETECTION
- ENGINE BLEED-AIR VALVE
- FIRE EXTING BOTTLE VALVES
- CORE RPM-N_{II}
- FAN RPM-N_{I}
- FUEL FLOWRATE
- OIL QUANTITY
- ENGINE VIBRATION (REAR CORE BEARING)
- ENGINE VIBRATION (FRONT CORE BEARING)
- ENGINE VIBRATION (FAN BEARING)
- COMPRESSOR STATOR POSITION
- POWER LEVEL POSITION

⚠1 INSTALLED FOR FERRY MISSION ONLY

REVISIONS

LTR	ZONE	DESCRIPTION	DATE	APPROV

QTY REQD	QTY REQD	CODE IDENT NO	PART OR IDENTIFYING NO	NOMENCLATURE OR DESCRIPTION	STOCK	MATERIAL OR MATERIAL CODE	DRAWING OR SPECIFICATION NO	NOTE NO	ZONE
	FIND NO			PARTS LIST					

LOFT
DATA
LAYOUT
NO
TOLERANCE UNLESS NOTED
XX = ± .03
XXX = ± .010
FINISH
SPEC
CONTR
NO.

DR K. Jantzig 6.10.71
CHK H. Hill 5.28.71
STR
QA Jon H. Emanuel 5.27.71
PROP Jim F. Stockman 5.27.71
Tech G.M. Rogers

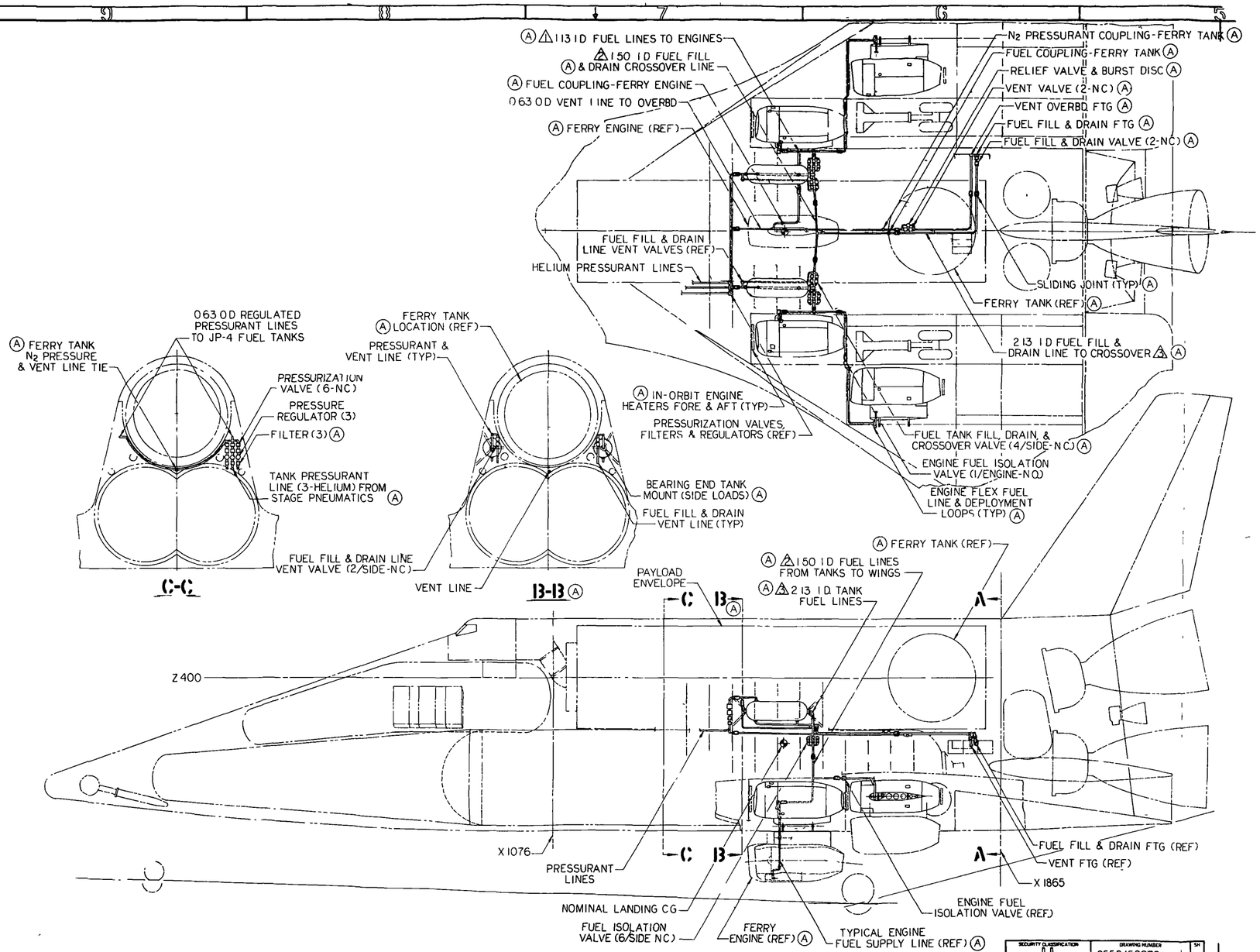
McDONNELL DOUGLAS ASTRONAUTICS COMPANY – EASTERN DIVISION
McDONNELL DOUGLAS CORPORATION

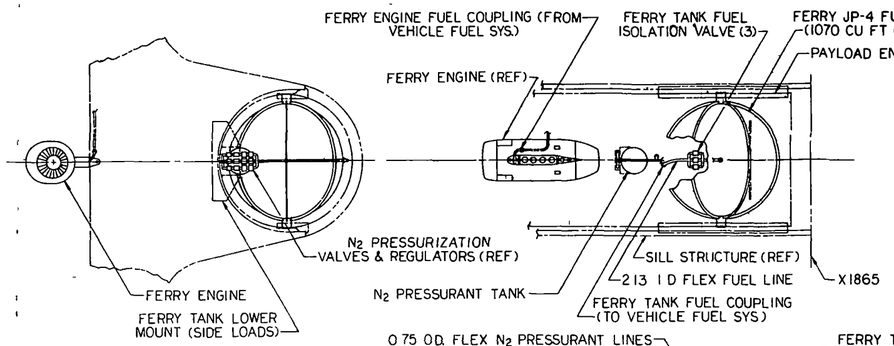
AIRBREATHING ENGINE INSTALLATION-ORBITER

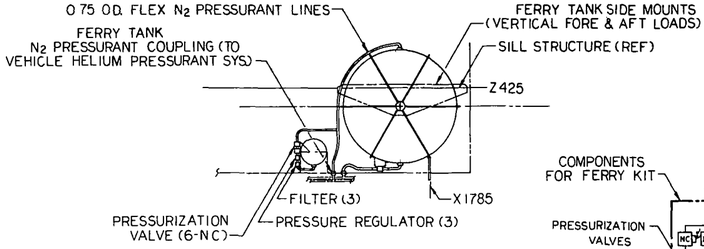
DASH NO	FIN ART	NEXT ASSY	USED ON
	QTY REQD	APPLICATION	

SIZE J | CODE IDENT NO 76301 | 255BJ50147
SCALE 1/10 WT LB SHEET

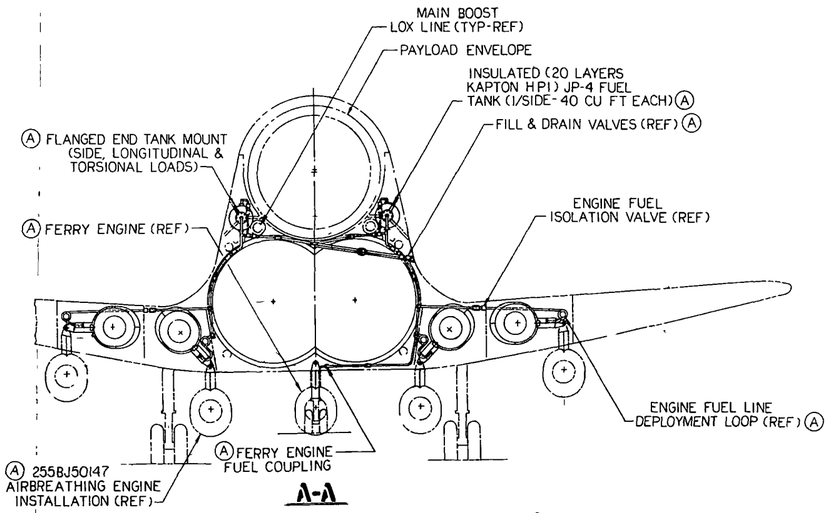
255BJ50147


Ⓐ △1131D FUEL LINES TO ENGINES
△150 ID FUEL FILL Ⓐ & DRAIN CROSSOVER LINE
Ⓐ FUEL COUPLING-FERRY ENGINE
063 OD VENT LINE TO OVERBD
Ⓐ FERRY ENGINE (REF)
N2 PRESSURANT COUPLING-FERRY TANK Ⓐ
FUEL COUPLING-FERRY TANK Ⓐ
RELIEF VALVE & BURST DISC Ⓐ
VENT VALVE (2-NC) Ⓐ
VENT OVERBD FTG Ⓐ
FUEL FILL & DRAIN FTG Ⓐ
FUEL FILL & DRAIN VALVE (2-NC) Ⓐ
FUEL FILL & DRAIN LINE VENT VALVES (REF)
HELIUM PRESSURANT LINES
SLIDING JOINT (TYP) Ⓐ
FERRY TANK (REF) Ⓐ
213 ID FUEL FILL & DRAIN LINE TO CROSSOVER △ Ⓐ
Ⓐ IN-ORBIT ENGINE HEATERS FORE & AFT (TYP)
PRESSURIZATION VALVES, FILTERS & REGULATORS (REF)
FUEL TANK FILL, DRAIN, & CROSSOVER VALVE (4/SIDE-NC) Ⓐ
ENGINE FUEL ISOLATION VALVE (1/ENGINE-NO)
ENGINE FLEX FUEL LINE & DEPLOYMENT LOOPS (TYP) Ⓐ
063 OD REGULATED PRESSURANT LINES TO JP-4 FUEL TANKS
Ⓐ FERRY TANK N2 PRESSURE & VENT LINE TIE
PRESSURIZATION VALVE (6-NC)
PRESSURE REGULATOR (3)
FILTER (3) Ⓐ
TANK PRESSURANT LINE (3-HELIUM) FROM STAGE PNEUMATICS Ⓐ
FUEL FILL & DRAIN LINE VENT VALVE (2/SIDE-NC)
C-C
FERRY TANK Ⓐ LOCATION (REF)
PRESSURANT & VENT LINE (TYP)
VENT LINE
B-B Ⓐ
BEARING END TANK MOUNT (SIDE LOADS) Ⓐ
FUEL FILL & DRAIN VENT LINE (TYP)
Ⓐ FERRY TANK (REF)
Ⓐ △150 ID FUEL LINES FROM TANKS TO WINGS
Ⓐ △213 ID TANK FUEL LINES
PAYLOAD ENVELOPE
Z 400
X 1076
PRESSURANT LINES
NOMINAL LANDING CG
FUEL ISOLATION VALVE (6/SIDE NC)
FERRY ENGINE (REF) Ⓐ
TYPICAL ENGINE FUEL SUPPLY LINE (REF) Ⓐ
ENGINE FUEL ISOLATION VALVE (REF)
X 1865
VENT FTG (REF)
FUEL FILL & DRAIN FTG (REF)
SECURITY CLASSIFICATION
U
DRAWING NUMBER
255BJ50070 REV A
SH

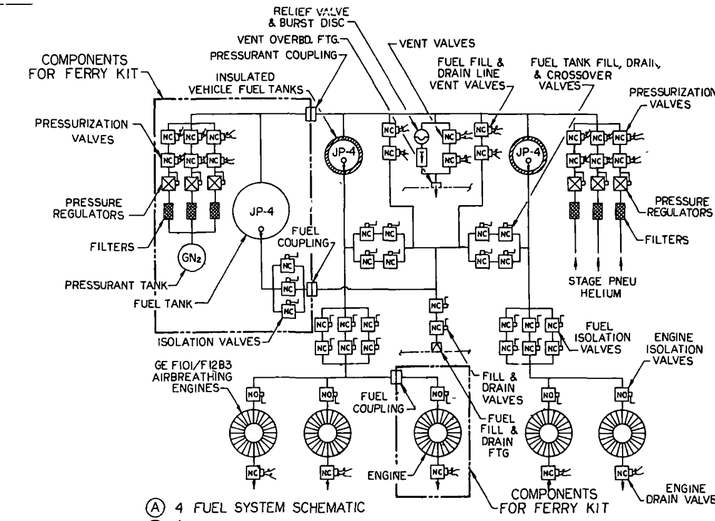

FERRY ENGINE FUEL COUPLING (FROM VEHICLE FUEL SYS.)
FERRY TANK FUEL ISOLATION VALVE (3)
FERRY JP-4 FUEL TANK (1070 CU FT CAPACITY)
PAYLOAD ENVELOPE (REF)
FERRY ENGINE (REF)
N2 PRESSURIZATION VALVES & REGULATORS (REF)
SILL STRUCTURE (REF)
213 I D FLEX FUEL LINE
X1865
FERRY ENGINE
FERRY TANK LOWER MOUNT (SIDE LOADS)
N2 PRESSURANT TANK
FERRY TANK FUEL COUPLING (TO VEHICLE FUEL SYS)


0 75 OD. FLEX N2 PRESSURANT LINES
FERRY TANK SIDE MOUNTS (VERTICAL FORE & AFT LOADS)
FERRY TANK N2 PRESSURANT COUPLING (TO VEHICLE HELIUM PRESSURANT SYS)
SILL STRUCTURE (REF)
Z425
FILTER (3)
X1785
PRESSURIZATION VALVE (6-NC)
PRESSURE REGULATOR (3)

FERRY TANK SYSTEM INSTALLATION (A)


MAIN BOOST LOX LINE (TYP-REF)
PAYLOAD ENVELOPE
INSULATED (20 LAYERS KAPTON HP1) JP-4 FUEL TANK (1/SIDE- 40 CU FT EACH) (A)
FILL & DRAIN VALVES (REF) (A)
(A) FLANGED END TANK MOUNT (SIDE, LONGITUDINAL & TORSIONAL LOADS)
(A) FERRY ENGINE (REF)
ENGINE FUEL ISOLATION VALVE (REF)
ENGINE FUEL LINE DEPLOYMENT LOOP (REF) (A)
(A) FERRY ENGINE FUEL COUPLING
(A) 255BJ50147 AIRBREATHING ENGINE INSTALLATION (REF)

A-A



(A) 4 FUEL SYSTEM SCHEMATIC

(A) ⚠3 213 ID FUEL LINES JACKETED WITH 250 OD PRESSURE TIGHT TUBING

(A) ⚠2 150 ID FUEL LINES JACKETED WITH 187 OD PRESSURE TIGHT TUBING

(A) ⚠1 113 ID FUEL LINES JACKETED WITH 150 OD PRESSURE TIGHT TUBING

NOTES

LTR	ZONE	REVISIONS DESCRIPTION	DATE	APPROVED
A		ADDED – FUEL SYSTEM SCHEMATIC FERRY TANK & ENGINE INSTALLATION FUEL TANK & FILL LINE DIAMETERS REFERENCE TO IN-ORBIT ENGINE HEATERS FILTERS IN He PRESSURIZATION PACKAGE ENGINE POD FUEL LINE DEPLOYMENT LOOP TWO ADDITIONAL FILL & DRAIN VALVES/PACKAGE FUEL TANK VOLUME REMOVED – VENT CROSSOVER LINE ONE VENT & RELIEF VALVE PACKAGE CHANGED – DIRECTION OF VIEW FOR SECTION B-B DIA OF CROSSOVER LINE – WAS 1.75 O.D. DIA OF ENGINE LINES – WERE 1.25 O.D. DIA OF FUEL LINE JACKET – WAS 2.00 O.D. LOCATION OF VENT & RELIEF VALVE PACKAGE P&W TO GE ENGINE INSTALLATION FUEL TANK MOUNTS – WERE SIDE MOUNTED REGULATORS & VALVE POSITIONS IN PRESS. PKG THREE He PRESS. SUPPLY LINES – WAS ONE FILL & DRAIN VALVES – WERE MANUAL CHECKVALVES SLIDING JOINTS – WERE BELLOWS LOCATION OF VENT TIE TO PRESS. LINE LOCATIONS OF FERRY SYS. FUEL & PRESS. TIES ROUTING OF FUEL FILL & DRAIN VENT LINE ROUTING OF FUEL LINES TO ENGINES	8-4-71	M.K. SCHULTZ

QTY REQD	QTY REQD	CODE IDENT NO.	PART OR IDENTIFYING NO.	DRAWING OR SPECIFICATION NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL OR MATERIAL CODE	NOTE NO.	ZONE
	FIND NO.				PARTS LIST				

LOFT DATA	DR C. BAGGETT	10/71	MCDONNELL ST LOUIS, MISSOURI
LAYOUT NO.	CHECK		
TOLERANCE UNLESS NOTED	STR		
X = ± 1	OR Lead Engineer	11/71	AIRBREATHING ENGINE FUEL SYSTEM INSTAL – ORBITER
XX = ± .03	Project Eng. Design	12/71	
.XXX = ± .010	Design Eng. Approval	12/71	
FINISH SPEC		12/71	
CONTR NO.			

DASH NO.	ASSY	ART	NEXT ASSY	USED ON
	QTY REQD		APPLICATION	

SIZE	CODE IDENT NO.	255BJ50070 REV-A
J	78301	
SCALE 1/50	WT	LB SHEET

2.8 Propulsion - Auxiliary — 11877

		Page No.
Attitude Control	[9957]	
Thruster Installation	(1291)	2.8-3
Thruster	1038	
Accessory	253	
Propellant System	(3664)	
Fill/Drain	423	2.8-4
Pressurization	444	2.8-5
Vent	150	2.8-6
Feed System	892	2.8-7
Accumulators	1062	2.8-9
Conditioning Equipment	693	2.8-9
Tankage	(3935)	2.8-10
Tanks	1749	
Insulation	1648	
Supports	538	
Contingency	(1067)	2.8-2
Maneuver	[1920]	
Thruster Installation	(667)	2.8-3
Thruster	607	
Accessory	60	
Propellant System	(1112)	
Feed System	1112	2.8-8
Contingency	(141)	2.8-2

Section 2.8

The auxiliary propulsion system weight was calculated using drawings numbered 255BJ50146 and 255BJ50907, and the propulsion system schematic. Weight was included for couplings, supports, wiring and installation parts where experience indicates these items will be required.

A contingency was added to the total system weight to provide for items which may have been overlooked. Experience indicates, as shown in section 1, that a contingency allowance is needed at this stage of design maturity to assure a 50% probability that the weight will not be exceeded.

The following notes apply to this section:

- Valve weight correlations are presented on pages 2.6-14 thru 2.6-16.
- Angulation and sliding joint weights are based on the method presented on pages 2.6-17 thru 2.6-23.
- Coupling weights were derived from vendor catalog data and include flanges, seals and coupling devices.
- APS engine, high pressure regulator, heat exchanger, and turbopump weights are based on parametric data generated by the Space Shuttle Auxiliary Propulsion Definition Study. Applicable parametric data from that study is presented on pages 2.8-18 thru 2.8-23.

AUXILIARY PROPULSION SUMMARY

8 PROPULSION – AUXILIARY		ATT. CONTROL	.	MANEU-VER	11877
THRUSTER INSTALLATION		1291		667	
THRUSTER	1038		607		
ACCESSORY	253		60		
PROPELLANT SY		3664		1112	
FILL/DRAIN	423		← INCL		
PRESSURIZATION	444		← INCL		
VENT	150		← INCL		
FEED SYSTEM	892		1112		
ACCUMULATORS	1062		N/A		
CONDITIONING EQUIPMENT	693		N/A		
TANKAGE		3935		← INCL	
TANKS	1749				
INSULATION	1648				
SUPPORTS	538				
CONTINGENCY		1067		141	

DESIGN DATA SUMMARY

8 PROPULSION – AUXILIARY

THRUSTERS THRUST (VAC) – LB	I_{SP} – SEC	ACS	QUANTITY REQ MANEUVER	COMBIN	
15000	444	0	2	0	(2)
1600	379	2	2	0	(2)
1600	360/379	0	0	28	(28)
					( )
					( )

PROPELLANT SYS	TYPE	TANK** VOLUME	TANK MATL	TANK PRES PSI	BURST FACTOR	NO OF TANKS
FUEL	LH2	2464 FT³	AL	32	2	1
OXIDIZER	LOX	282.5 FT³ EA.	AL	41	2	2
FUEL PRESSURANT }	He	12.1 FT³	AL	3000	2	1
OXIDIZER PRESS }						

** NET USABLE H2 VOLUME

NOTE; SEE DWG NO. 255BJ50146 (PAGE 2.8-25)

AUXILIARY PROPULSION

		WT.–LB
THRUSTER INSTALLATION		
ATTITUDE CONTROL	QTY	(1290.9)
1600 LB THRUST ACS THRUSTERS	(30) @ 34.61 LB	1038.3
THRUSTER WT. INCLUDES MTG. FLANGE & GAS SEAL @ M–		
INSTALLATION STRUCT.	(30) @ 4.20 LB (TYPICAL ASSY)	126.0
ENGINE COVERS (SEE DWG. NO. 255BJ50907, PAGE 2.8-26)		
FWD R.H. SIDE		18.3
ACTUATOR	5.5 LB	
DOOR & INSULATION (LAYOUT CALC)	22.4 LB	
LESS TPS SHINGLE & INSULATION	–12.6 LB	
LINKAGE & HINGE	3.0 LB	
FWD L.H. SIDE (SAME AS R.H. SIDE)		18.3
AFT ℄		37.5
ACTUATOR	11.0 LB	
DOOR & INS	44.5 LB	
LESS TPS SHINGLE & INSULATION	–14.5 LB	
LINKAGE & HINGE	6.5 LB	
WIRING, CONNECTORS & INSTL.		52.6
MANEUVER		(667.0)
RL-10 (15000 LB THRUST)	(2) @ 303.5 LB	607.0
INSTALLATION STRUCT. (2) @ 28.5 LB EA		57.0
WIRING, CONNECTORS & INSTL.		3.0

FILL & DRAIN

	QTY	WT~LB
COLD He		(25.4)
FILL VALVE (QUICK DISCONNECT) ½ IN.	(1) @ .75LB	.8
FILTER ½ IN.	(1) @ 1.50LB	1.5
CHECK VALVES ¼ IN.	(2) @ .15LB	.3
N.C. SOLENOID VALVES ½ IN.	(2) @ .80LB	1.6
HAND VALVES ¼ IN.	(2) @ .25LB	.5
CAP	(1) @ .005LB	.1
BURST DISC.	(1) @ .13LB	.1
LINES ½ IN. .028 S.S.	1200 IN. @ .012LB/IN	14.4
INSULATION	1200 IN. @ .0051 LB/IN	6.1
HYDROGEN ACCUMULATOR GROUND FILL		(10.3)
FILL VALVE (QUICK DISC.) ¼ IN.	(1) @ .5LB	.5
FILTER ¼ IN.	(1) @ .8LB	.8
CHECK VALVE ¼ IN	(2) @ .15LB	.3
LINES ¼ IN. .0163 S.S.	1200 IN. @ .0036LB/IN	4.3
INSULATION	1200 IN. @ .0037LB/IN	4.4
OXYGEN ACCUMULATOR GROUND FILL		(3.4)
FILL VALVE (QUICK DISC.) ¼ IN.	(1) @ .5LB	.5
FILTER ¼ IN.	(1) @ .8LB	.8
CHECK VALVE ¼ IN.	(2) @ .15LB	.3
LINES ¼ IN. .016 S.S.	250 IN. @ .0036LB/IN	.9
INSULATION	250 IN. @ .0037LB/IN	.9
HYDROGEN TANK GROUND FILL		(51.7)
FILL VALVE (QUICK DISC.) 2 IN.	(1) @ 2.00	2.0
N.C. PNEUMATIC (WITH DUAL SOLENOIDS)	(2) @ 6.25LB	12.5
LINE 2 IN. 029 AL	1200 IN. @ .0174LB/IN	20.9
INSULATION	1200 IN @ .0136LB/IN	16.3
OXYGEN TANK GROUND FILL		(22.4)
FILL VALVE (QUICK DISC.) 2 IN.	(1) @ 2.00	2.0
N.C. PNEUMATIC (WITH DUAL SOLENOIDS)	(2) @ 6.25	12.5
LINE 2 IN.	250 IN. @ .0174LB/IN	4.4
INSULATION	250 IN. @ .0136LB/IN	3.5
HYDROGEN START TANK FILL		(159.0)
N.C. PNEUMATIC 4 IN.	(3) @ 19.LB	57.0
CHECK VALVES 4 IN.	(6) @ 17.LB	102.0
OXYGEN START TANK FILL		(66.0)
N.C. PNEUMATIC 2½ IN.	(3) @ 8.0LB	24.0
CHECK VALVES 2½ IN.	(6) @ 7.0LB	42.0
CONNECTORS. SUPPORTS & MISC		84.6
TOTAL FILL & DRAIN		422.8

PRESSURIZATION SYSTEM

		WT - LB
TANK – COLD HELIUM	2219 AL (FTU@-423°F = 104500)	206.1
PRESS = 3000 PSI	MAX. OPR. ; 6000 PSI BURST	
I.D. = 34.18 IN.	$A_{REA@EQFT} = 4\pi R^2 = 3778.4\ IN^2$	
$t = \frac{BURST\ PRESS * R}{2 * FTU} = \frac{6000 * 17.34}{2 * 104500.} = .498$		
$WT. = NONDIT * t * AREA * \rho$		
$= 1.08 * .500 * 3778.4 * .101 = 206.07\ LB$		
$VOLUME = 4/3\ \pi R^3 = 12.1\ FT^3$		
TANK SUPPORTS & MISC.		30.9
COLD He PRESS SUPPLY	QTY	
FILTERS ½ IN. LINE DIA	(3) @ 1.50 LB	4.5
VALVES ½ IN. LINE DIA.	(9) @ .80 LB	7.2
ORFICES ½ IN. LINE DIA.	(3) @ .03 LB	.1
LINES ½ IN. .016 S.S	1300 IN. @ .007 LB/IN.	9.1
TANK PRESSURIZATION		
H_2 START TK PRESS VALVES	(9) @ 7.67 LB	69.0
O_2 START TK PRESS VALVES	(9) @ 2.06 LB	18.5
H_2 MAIN TK PRESS VALVES	(9) @ 3.55 LB	31.9
O_2 MAIN TK PRESS VALVES	(9) @ .98 LB	8.8
H_2 DIFFUSER	(1) @ 1.5 LB	1.5
H_2 LINES 2¼ IN. LINES	100 IN. @ .031 LB/IN.	3.1
O_2 LINES 1 IN. LINES	100 IN. @ .015 LB/IN.	1.5
H_2 LINES 1½ IN. LINES	300 IN. @ .022 LB/IN.	6.6
O_2 LINES ⅝ IN. LINES	400 IN. @ .009 LB/IN.	3.6
CONNECTORS, SUPPORTS & MISC		41.4
TOTAL ACPS PRESSURIZATION SYSTEM		443.8

VENT SYSTEM

	QTY	WT.-LB.
H_2 START TANK VENT VALVES	(9) @ 3.00	27.0
O_2 START TANK VENT VALVES	(9) @ 2.88	25.9
H_2 MAIN TANK VENT VALVES	(6) @ 2.91	17.5
O_2 MAIN TANK VALVES	(6) @ 2.91	17.5
H_2 NON-PROPULSIVE VENT	(1) @ 3.0	3.0
H_2 GROUND VENT (QUICK DISC.)	(1) @ 1.75	1.8
H_2 VENT LINE .028AL 1.5 IN. DIA.	1400 IN. @ .013 LB/IN	18.2
O_2 NON-PROPULSIVE VENT	(1) @ 3.0	3.0
O_2 GROUND VENT (QUICK DISC.)	(1) @ 1.75	1.8
O_2 VENT LINE .028 AL 1.5 IN. DIA	300 IN. @ .013 LB/IN	3.9
CONNECTORS, SUPPORTS & MISC.		30.0
TOTAL VENT SYSTEM		149.6

FEED SYSTEM

	QTY			WT ~ LB
ATTITUDE CONTROL				
H_2 HEAT EXCHANGER CHECK VALVE	(2)	@	1.35	4.1
O_2 HEAT EXCHANGER CHECK VALVE	(3)	@	1.33	4.0
H_2 ACCUMULATOR RELIEF VALVE	(2)	@	5.20	10.4
O_2 ACCUMULATOR RELIEF VALVE	(2)	@	5.16	10.3
H_2 LINE PNEUMATIC VALVE	(5)	@	4.85	24.3
O_2 LINE PNEUMATIC VALVE	(5)	@	4.76	23.8
H_2 ENGINE LINE REG.	(3)	@	6.72	20.2
O_2 ENGINE LINE REG.	(3)	@	6.14	18.4
H_2 REG. RELIEF VALVE	(2)	@	4.99	10.0
O_2 REG. RELIEF VALVE	(2)	@	4.96	9.9
H_2 ENGINE PNEUMATIC VALVES	(60)	@	1.86	111.6
O_2 ENGINE PNEUMATIC VALVES	(60)	@	1.83	109.8
GH_2 ISOLATION VALVES	(12)	@	1.28	15.4
GO_2 ISOLATION VALVES	(12)	@	1.26	15.1
PUMP INLET SHUTOFF H_2 VALVES	(9)	@	3.97	35.7
PUMP INLET SHUTOFF O_2 VALVES	(9)	@	2.97	26.8
LH_2 CHECK VALVES	(12)	@	1.06	12.7
LO_2 CHECK VALVES	(12)	@	.84	10.1
H_2 LINES TK TO COND.				
LINES 1.43 IN.; .028	360. IN. @ .0127 LB/IN.			4.6
JACKETS 3.75 IN.; .028 CONVOLUTED	360. IN. @ .0523 LB/IN.			18.8
INSULATION	360. IN. @ .025 LB/IN.			9.0
HEAT EXCHANGER TUBE .31 IN.; .020	720. IN. @ .002 LB/IN.			1.4
O_2 LINES TK TO COND.				
LINES 1.16 IN.; .028	290. IN. @ .0103 LB/IN.			3.0
JACKETS 3.35 IN.; .028 CONVOLUTED	290. IN. @ .0468 LB/IN.			13.6
INSULATION	290. IN. @ .021 LB/IN.			6.1
HEAT EXCHANGER TUBE .19 IN.; .020	580. IN. @ .0012 LB/IN.			.7
H_2 DISTRIBUTION LINES				
LINES 1.65 IN.; .028	3300. IN. @ .0147 LB/IN.			48.5
INSULATION	3300. IN. @ .0116 LB/IN.			38.3
O_2 DISTRIBUTION LINES				
LINES 1.63 IN.; .028	2950. IN. @ .0145 LB/IN.			42.8
INSULATION	2950. IN. @ .0115 LB/IN.			33.9
H_2 HOOK UP LINES				
LINES .825 IN.; .028	720. IN. @ .0073 LB/IN.			5.3
INSULATION	720. IN. @ .0070 LB/IN.			5.0
O_2 HOOK UP LINES				
LINES .815 IN.; .028	720. IN. @ .0072 LB/IN.			5.2
INSULATION	720. IN. @ .0069 LB/IN.			5.0
CONNECTORS, SUPPORTS & MISC.				178.5
TOTAL ATTITUDE CONTROL FEED SYSTEM				892.3

FEED SYSTEM

		Wt ~ LB
MANEUVER		
H_2 VALVES		
N.O. PNEUMATIC VALVES 3.9 IN. DIA.	(4) @ 18.0 LB.	76.0
N.O. PNEUMATIC VALVES 3.1 IN. DIA.	(4) @ 11.5 LB.	46.0
N.C. SOLENOID VALVES (LINE DUMP) ¼ IN DIA	(9) @ .22 LB	2.0
O_2 VALVES		
N.O. PNEUMATIC VALVES 2.65 IN. DIA.	(4) @ 8.7 LB.	34.8
N.O. PNEUMATIC VALVES 2.15 IN. DIA.	(4) @ 6.0 LB.	36.0
N.C. SOLENOID VALVES (LINE DUMP) ¼ IN. DIA.	(9) @ .22 LB	2.0
H_2 FEED LINES		
FULL FLOW LINES 3.9 IN. ; .020 WALL S.S.	954 IN. @ .0711 LB/IN.	67.8
FULL FLOW JACKET 7.3 IN. ; .012 WALL S.S. (CONV.)	954 IN. @ .1259 LB/IN	119.6
INSULATION	954 IN. @ .0571 LB/IN	54.5
HEAT EXCHANGER TUBE .31 IN. ; .012 S.S.	2000 IN. @ .0034 LB/IN	6.8
SPLIT FLOW LINES 3.1 IN. ; .020 WALL S.S.	796 IN. @ .0565 LB/IN	45.0
SPLIT FLOW JACKET 6.2 IN. ; .012 WALL S.S. (CONV.)	796 IN. @ .1065 LB/IN	84.8
INSULATION	796 IN. @ .0563 LB/IN	44.8
HEAT EXCHANGER TUBE .31 IN. ; .012 S.S.	1600 IN. @ .003A LB/IN	5.4
O_2 FEED LINES		
FULL FLOW LINES 2.65 IN. ; .016 WALL S.S.	416 IN. @ .0396 LB/IN	15.8
FULL FLOW JACKET 5.91 IN ; .012 WALL S.S. (CONV.)	416 IN. @ .1015 LB/IN.	42.4
INSULATION	416 IN @ .0587 LB/IN	24.4
HEAT EXCHANGER TUBE .185 ; .012 WALL S.S.	900 IN. @ .0020 LB/IN	1.8
SPLIT FLOW LINES 2.15 ; .016 WALL S.S.	110 IN. @ .0313 LB/IN.	3.4
SPLIT FLOW JACKET 5.21 ; .012 WALL S.S. (CONV.)	110 IN @ .0895 LB/IN	9.8
INSULATION	110 IN. @ .0473 LB/IN	5.2
HEAT EXCHANGER TUBE .185 ; .012 WALL S.S.	250 IN. @ .0020 LB/IN	.5
SLIDING JOINTS (JACKETED)		
3.9 IN. I.D.	(4) @ 3.7 LB	14.8
3.1 IN. I.D.	(5) @ 2.5 LB	12.5
2.65 IN. I.D.	(5) @ 2.0 LB	10.0
2.15 IN. I.D.	(2) @ 1.5 LB	3.0
COUPLINGS		
3.9 IN. STL/STL	(11) @ 6.6 LB	72.6
3.1 IN. STL/STL	(10) @ 5.4 LB	54.0
2.65 IN. STL/STL	(8) @ 4.9 LB	39.2
2.15 IN STL/STL	(8) @ 4.0 LB	32.0
SUPPORTS & MISC.		145.0
TOTAL MANEUVER FEED SYSTEM		1111.9

CONDITIONING EQUIP

	No. STAGES	APPROX. NPSP PSI	FLOW RATE LB/SEC	APPROX. ΔP PSIA	QTY		WT. ~LB
TURBO-PUMPS							
H_2 PUMPS	2	8	3.75	2000+	(3) @	28.53	85.6
O_2 PUMPS	1	20	13.0	2000+	(3) @	46.20	138.6
HEAT EXCHANGERS							
H_2 H.X.			3.75		(3) @	73.07	219.2
O_2 H.X.			13.0		(3) @	49.27	147.8
GAS GENERATORS							404
EQUIPMENT SUPPORTS							27.9
MISCELLANEOUS							33.0
CONDITIONING EQUIPMENT							692.5

ACCUMULATORS

GOX ACCUMULATOR (1) — 255.7

PRESS = 2140 PSI MAX. OPP.; 4280 PSI BURST

DIA = 36 IN. AREA = $4\pi R^2$ = 4071.5 IN^2

$t = \frac{\text{BURST PRESS} * R}{2 * FTU} = \frac{4280 * 18.00}{2 * 67500} = .570$

WT = NON-OPT * t * A * ρ

WT = 1.08 * .570 * 4071.5 * .102 = 255.7 LB

GH2 ACCUMULATOR (2) — 778.2

PRESS = 2140 PSI MAX. OPP; 4280 PSI BURST

DIA = 41.4 IN. AREA = $4\pi R^2$ = 5384.6 IN^2

$t = \frac{\text{BURST PRESS} * R}{2 * FTU} = \frac{4280. * 20.7}{2 * 67500} = .656$

WT = NON-OPT * t * A * ρ

WT = 1.08 * .656 * 5384.6 * .102 = 389.1

MOUNTS — 27.6

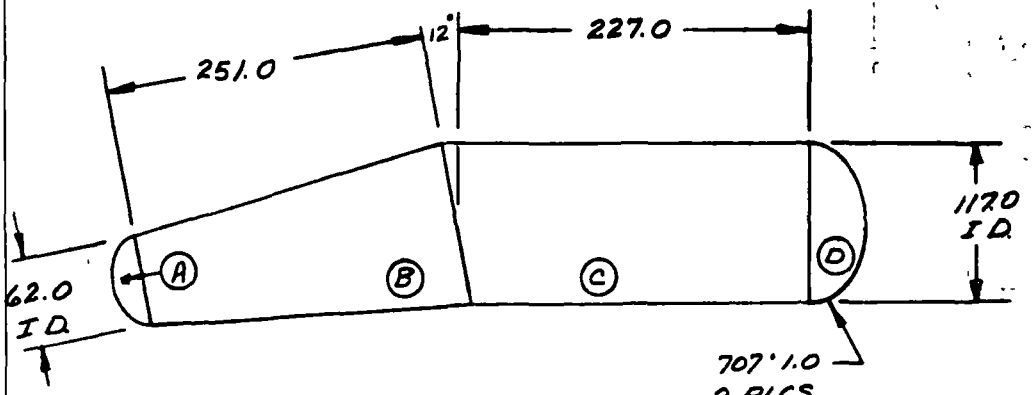
ACCUMULATORS & MOUNTS — 1061.5

TANKAGE SUMMARY

	O_2 START	H_2 START	LOX	LHZ	TOTAL
TANK	(96.8)	(252.5)	(483.0)	(916.8)	1749.1
SHELL	62.0	161.7	483.	916.8	
SCREEN	34.8	90.8	—	—	
INSULATION	(61.2)	(82.3)	(345.4)	(1159.2)	1648.1
INSULATION	60.6	81.7	308.2	1120.2	
VALVES	—	—	36.0	36.0	
HEAT EXCHANGER TUBING	.6	.6	—	—	
REPRESS TUBING	—	—	1.2	3.0	
SUPPORTS	(47.8)	(24.3)	(222.0)	(243.5)	537.6
TOTAL TANKAGE					3934.8

①

TANK, ACPS/OMS SECONDARY H_2



SECTION	AREA FT^2	VOLUME FT^3
(A)	34	32
(B)	493	940
(C)	579	1371
(D)	121	171

BURST PRESSURE = 64 PSI

MAT'L - 2219 ALUMINUM

FTU = 104500 PSI @ -423°F.

AFT BULKHEAD

$$\bar{t} = \frac{58.5 \times 64}{104500} = .036 \text{ IN}$$

WELD STIFF RING

WEIGHT = .036 × 121 × 144 × .101 × 1.1 × 1.15 × 1.25 = 100.2 LB.

FWD BULKHEAD

$$\bar{t} = \frac{31.0 \times 64}{104500} = .019 \text{ IN} \quad \text{(USE MIN. GAUGE .032)}$$

WEIGHT = .032 × 34 × 144 × .101 × 1.1 × 1.15 × 1.25 = 25.0 LB.

CONICAL SECTION

WEIGHT = .036 × 493 × 144 × .101 × 1.1 × 1.15 = 326.5 LB.

CYLINDRICAL SECTION

WEIGHT = .036 × 579 × 144 × .101 × 1.1 × 1.15 = 383.5 LB.

RING BETWEEN CONICAL & CYLIND. SECT (EST)	81.6	LB
INSULATION & COVER .913 LB/FT²		
WEIGHT = .913 LB/FT² × (34+493+579+121) =	1120.2	LB
SUB-TOTAL H_2 TANK	(2037.0	LB)
START TANK, H_2		
102 DIA		
VOLUME = 360 FT³		
AREA = $\frac{4\pi}{144}(51)^2$ = 2270 FT²		
SHELL (USE .032 MIN GAUGE)		
WEIGHT = .032 × 227 × 144 × .101 × 1.1 × 1.15 × 1.21 =	161.7	LB
INSULATION (.36 LB/FT²)		
WEIGHT = .36 × 227. =	81.7	LB
SCREEN & SUPPORTS (.2 LB/FT²)		
WEIGHT = 2 × 227 × .2 =	90.8	LB
SUPPORTS (10% OF SHELL & INSUL)		
WEIGHT = .10 × (161.7+81.7) =	24.3	LB
SUB-TOTAL START TANK	(358.5	LB)
INSULATION REPRESS VALVES (9 @ 2.0 LB)	(18.0	LB)
INSULATION VENT VALVES (9 @ 2.0 LB)	(18.0	LB)

(3)

HEAT EXCHANGER TUBING

ASSUME 400 IN. OF .25 IN. O.D. x .020 WALL ALUMINUM TUBING.

WEIGHT = .0014 x 400 = (.6 LB.)

INSULATION REPRESS TUBING

ASSUME 1000 IN OF .50 IN O.D. x .020 WALL ALUMINUM TUBING

WEIGHT = 0030 x 1000 = (3.0 LB)

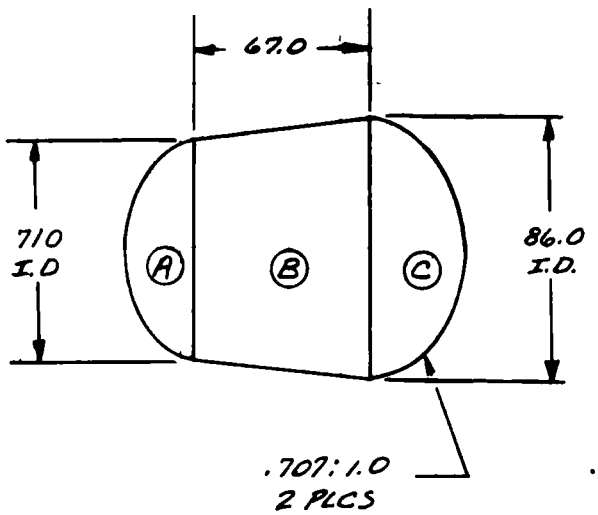
TOTAL SECONDARY H_2 TANK (DRY) 2435.1 LB.

SUPPORTS (EST 10% OF DRY TANK WEIGHT) (243.5 LB)

TOTAL TANK & SUPPORTS 2678.6 LB

(9)

TANK, ACPS/OMS SECONDARY O_2



SECTION	AREA FT²	VOLUME FT³
(A)	45	38.34
(B)	116	188.23
(C)	66	68.13

OPER. PRESSURE = 41 PSI.

TANK MAT'L - 2219 ALUMINUM

FTU = 79500 PSI @ -297°F.

GRAVITY HEAD (3 g's)

UPPER HEAD = $3 \times 71/1728 \times 71 =$ 8.7 PSI

LOWER HEAD = $3 \times 71/1728 \times 86 =$ 10.6 PSI

BURST PRESSURE (2 × (OPER + HEAD))

UPPER BULKHEAD = $2 \times (41 + 8.7) =$ 99.4 PSI

LOWER BULKHEAD = $2 \times (41 + 10.6) =$ 103.2 PSI

				⑤

UPPER BULKHEAD

$\bar{t} = \frac{35.5 \times 99.4}{79500} = .044$ IN.

WEIGHT = .044 × 45 × 144 × .101 × 1.1 × 1.15 × 1.25 = 455 LB

LOWER BULKHEAD

$\bar{t} = \frac{43.0 \times 1032}{79500} = .056$ IN.

WEIGHT = .056 × 66 × 144 × .101 × 1.1 × 1.15 × 1.25 = 850 LB

CONICAL SECTION (TAPERED SKIN)

$\bar{t} = .052$ IN.

WEIGHT = .052 × 116 × 144 × .101 × 1.1 × 1.15 = 1110 LB

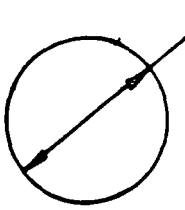
INSULATION (CRYO FOAM @ .679 LB/FT³)

WEIGHT = .679 × (45 + 116 + 66) = 154.1 LB

SUB-TOTAL SECONDARY O_2 TANK (395.6 LB)

(6)

START TANK, O_2



VOLUME = 60 FT^3

AREA = $\frac{4\pi}{144}(31.5)^2$ = 87 FT^2

SHELL (USE .032 MIN GAUGE)

WEIGHT = .032 x 87 x 144 x .101 x 1.1 x 1.15 x 1.21 = 62.0 LB

INSULATION (.697 LB/FT^2)

WEIGHT = .697 x 87 = 60.6 LB

SCREEN & SUPTS (.2 LB/FT^2)

WEIGHT = 2 x 87 x .2 = 34.8 LB

START TANK SUPTS

WEIGHT = .205 $(60 \times 70.6 + 620 + 606 + 34.8)^{.65}$ = 47.8 LB

SUBTOTAL START TANK (205.2 LB)

INSULATION REPRESS & VENT VALVES (18 @ 2. LB) (36.0 LB)

HEAT EXCHANGER TUBING

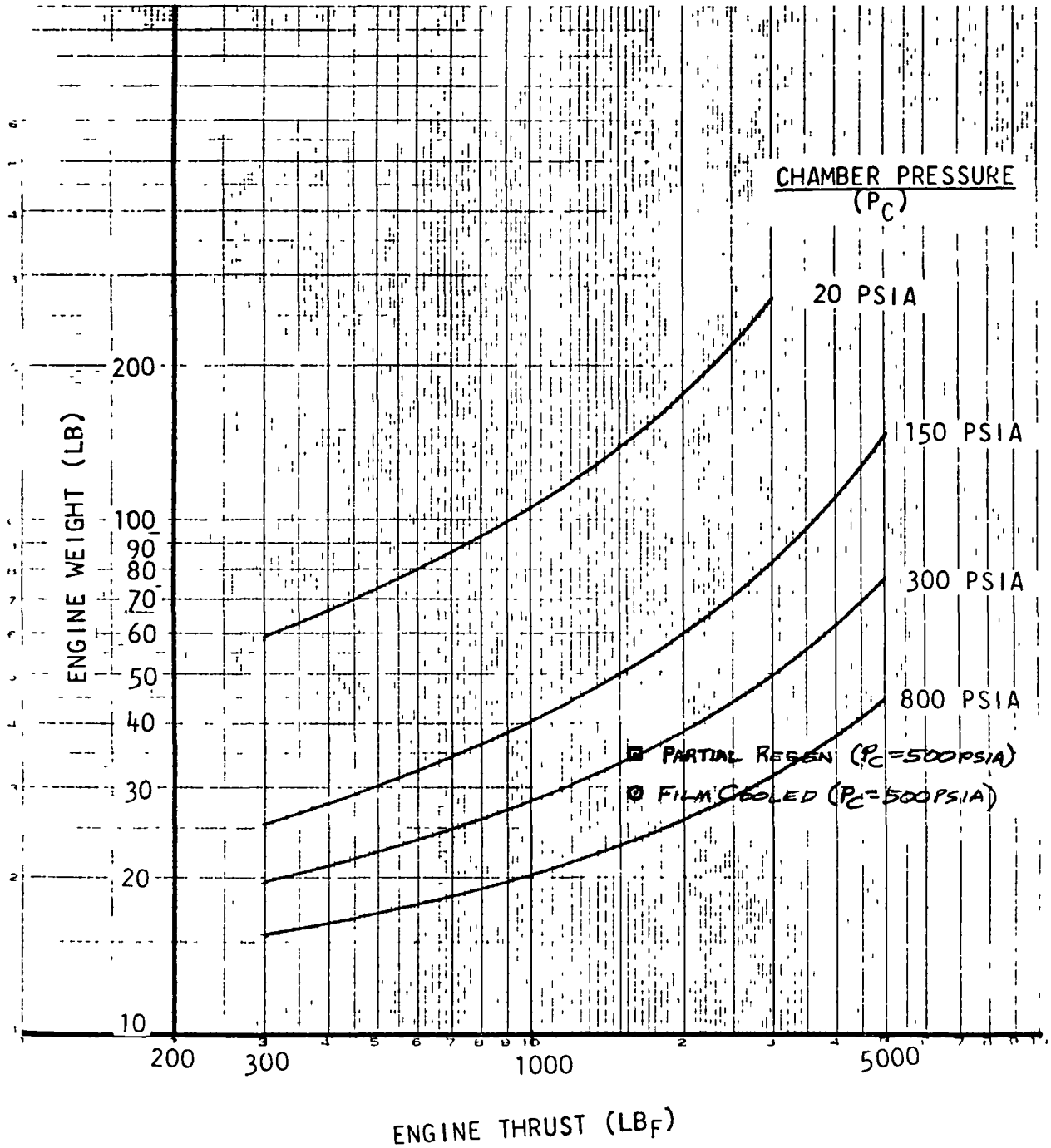
ASSUME 400 IN OF .25 OD x .020 WALL ALUMINUM TUBING

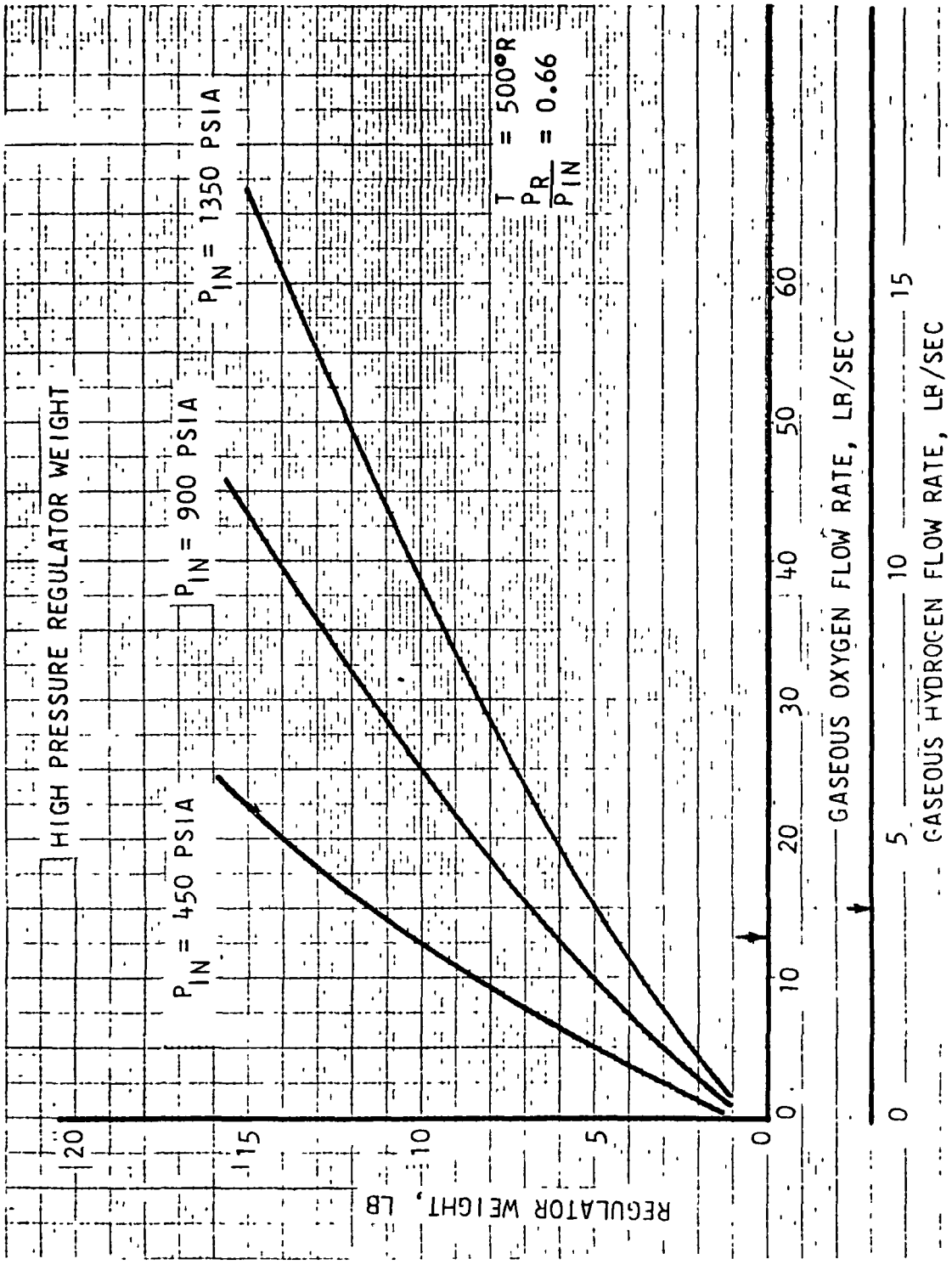
WEIGHT = .0014 x 400 (.6 LB)

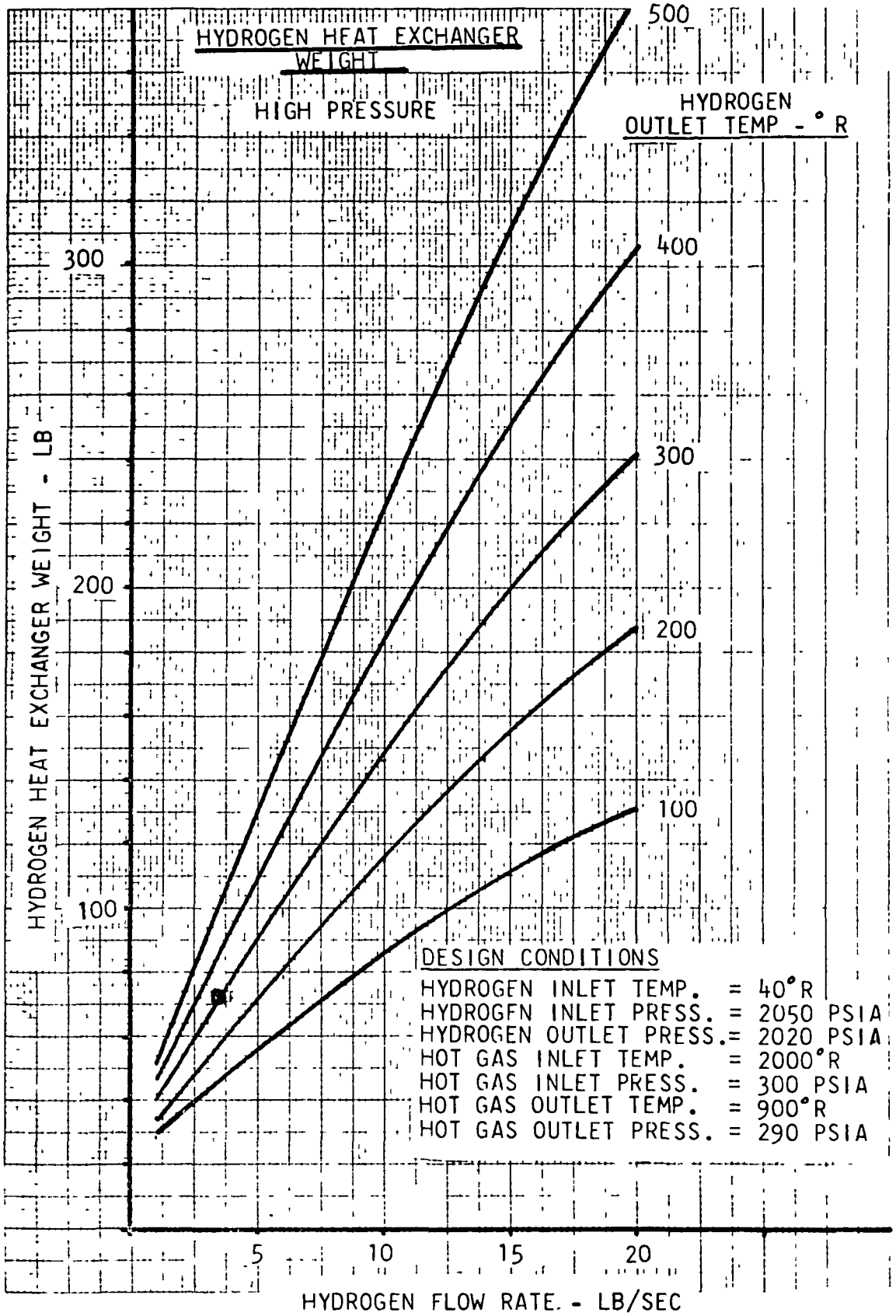
			⑦
		INSULATION REPRESS & VENT TUBING	
		ASSUME 200 IN OF .50 O.D. x .020 WALL ALUMINUM TUBING	
		WEIGHT = .0030 x 200	(.6 LB)
		SUB-TOTAL SECONDARY O_2 TANK (DRY)	638.0 LB
		TANK MOUNTS	
		WEIGHT = .205 (295 x 70.6 + 638.0)$^{.65}$ =	(111.0 LB)
		TOTAL SECONDARY O_2 TANK & SUPT	749.0 LB
		TOTAL FOR TWO (2) TANKS *	1256.2 LB

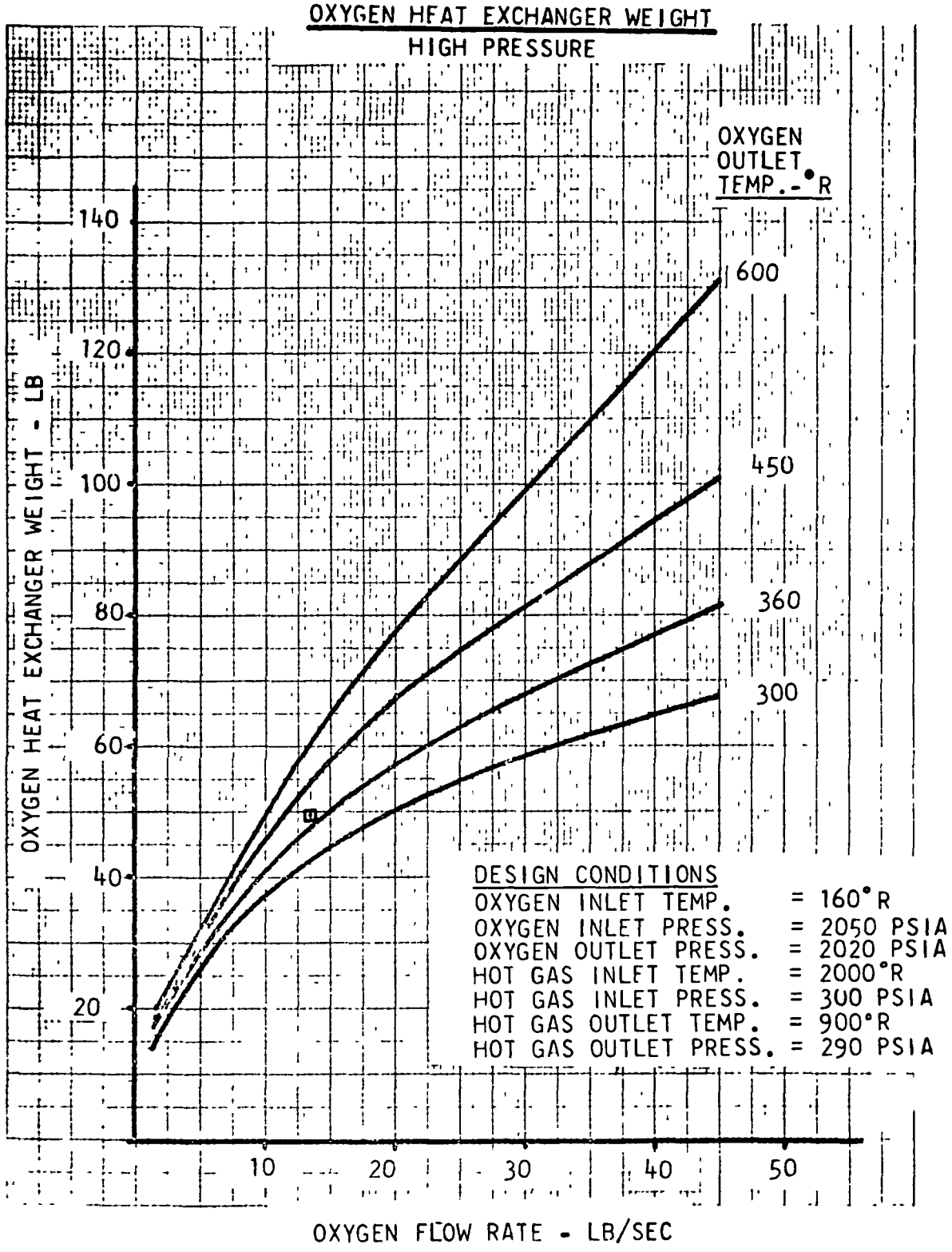
* INCLUDES ONE (1) START TANK AND EIGHTEEN (18) VALVES AND ONE (1) HEAT EXCHANGER.

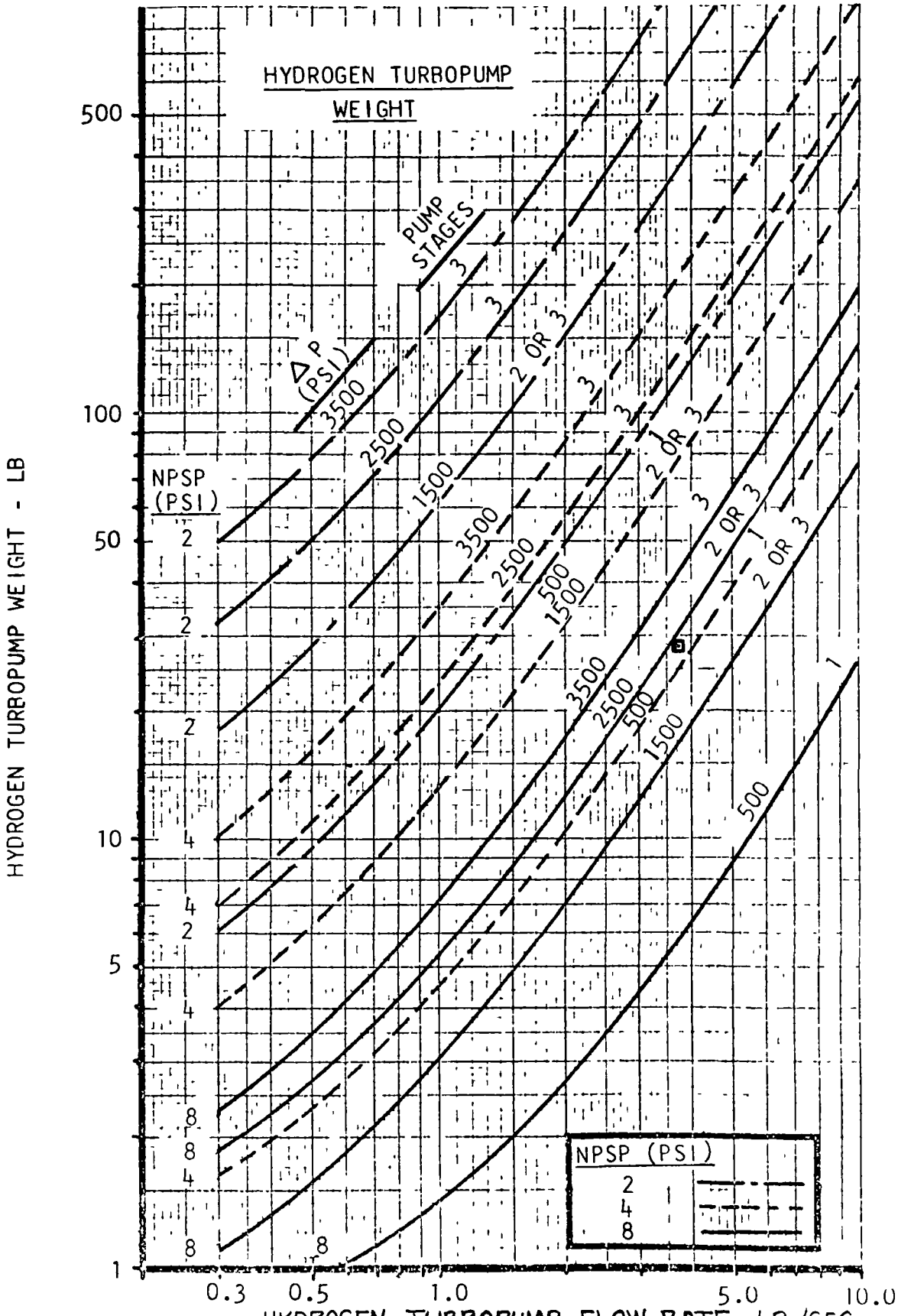
ENGINE WEIGHT
AS A FUNCTION OF THRUST
(AREA RATIO = 40)

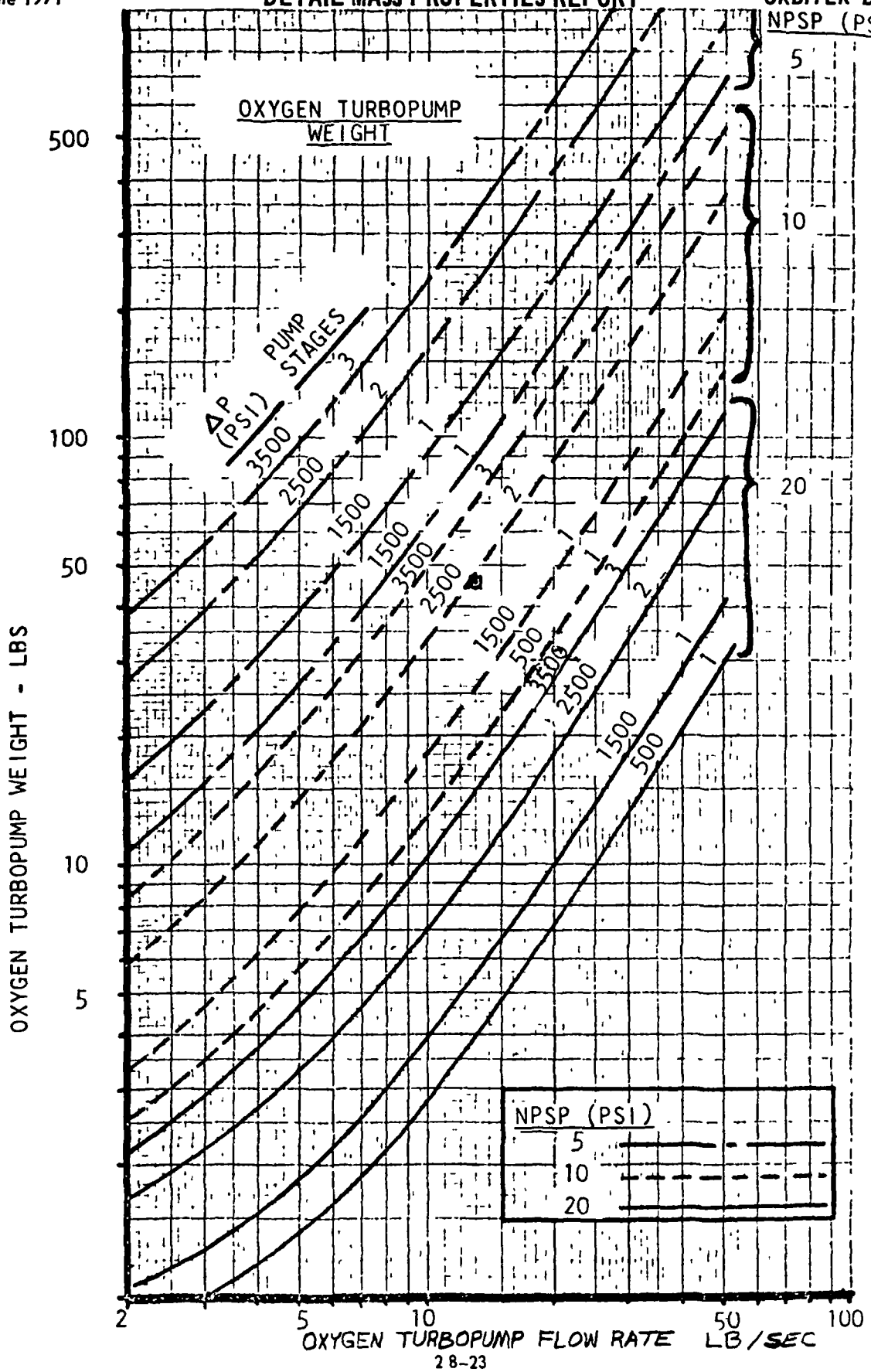



HIGH PRESSURE REGULATOR WEIGHT
REGULATOR WEIGHT, LB
P_{IN} = 450 PSIA
P_{IN} = 900 PSIA
P_{IN} = 1350 PSIA
T = 500°R
$\frac{P_R}{P_{IN}}$ = 0.66
GASEOUS OXYGEN FLOW RATE, LB/SEC
GASEOUS HYDROGEN FLOW RATE, LB/SEC
0
5
10
15
20
30
40
50
60


HYDROGEN HEAT EXCHANGER WEIGHT
HIGH PRESSURE
HYDROGEN OUTLET TEMP - °R
500
400
300
200
100
HYDROGEN HEAT EXCHANGER WEIGHT - LB
300
200
100
DESIGN CONDITIONS
HYDROGEN INLET TEMP. = 40°R
HYDROGEN INLET PRESS. = 2050 PSIA
HYDROGEN OUTLET PRESS. = 2020 PSIA
HOT GAS INLET TEMP. = 2000°R
HOT GAS INLET PRESS. = 300 PSIA
HOT GAS OUTLET TEMP. = 900°R
HOT GAS OUTLET PRESS. = 290 PSIA
5
10
15
20
HYDROGEN FLOW RATE - LB/SEC

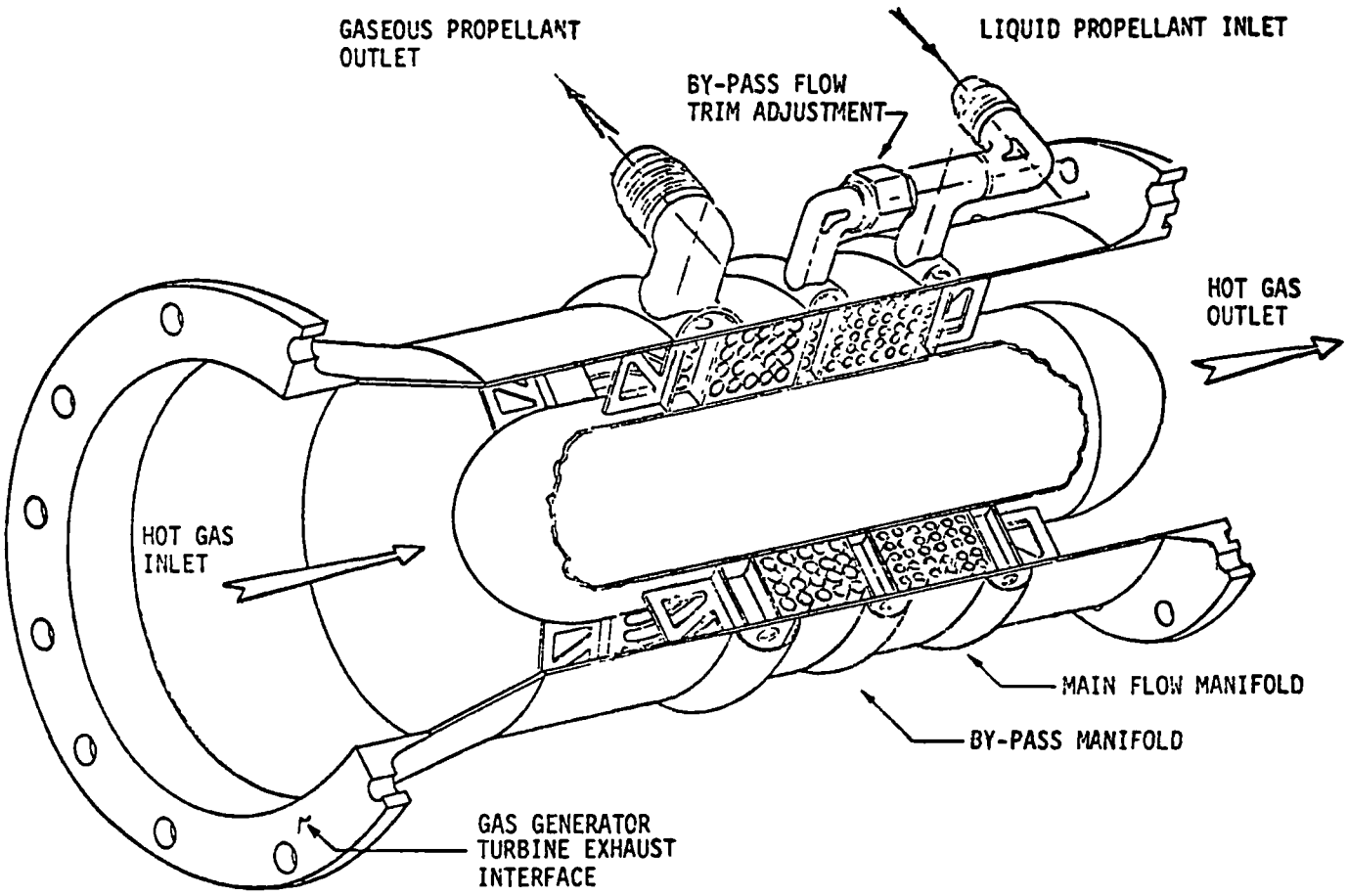

OXYGEN HEAT EXCHANGER WEIGHT
HIGH PRESSURE
OXYGEN OUTLET TEMP. - °R
600
450
360
300
OXYGEN HEAT EXCHANGER WEIGHT - LB
140
120
100
80
60
40
20
10
20
30
40
50
OXYGEN FLOW RATE - LB/SEC
DESIGN CONDITIONS
OXYGEN INLET TEMP. = 160°R
OXYGEN INLET PRESS. = 2050 PSIA
OXYGEN OUTLET PRESS. = 2020 PSIA
HOT GAS INLET TEMP. = 2000°R
HOT GAS INLET PRESS. = 300 PSIA
HOT GAS OUTLET TEMP. = 900°R
HOT GAS OUTLET PRESS. = 290 PSIA


HYDROGEN TURBOPUMP
WEIGHT
PUMP STAGES
ΔP (PSI)
NPSP (PSI)
HYDROGEN TURBOPUMP WEIGHT - LB
HYDROGEN TURBOPUMP FLOW RATE LB/SEC
500
100
50
10
5
1
0.3
0.5
1.0
5.0
10.0
3500
2500
1500
500
2 OR 3
NPSP (PSI)

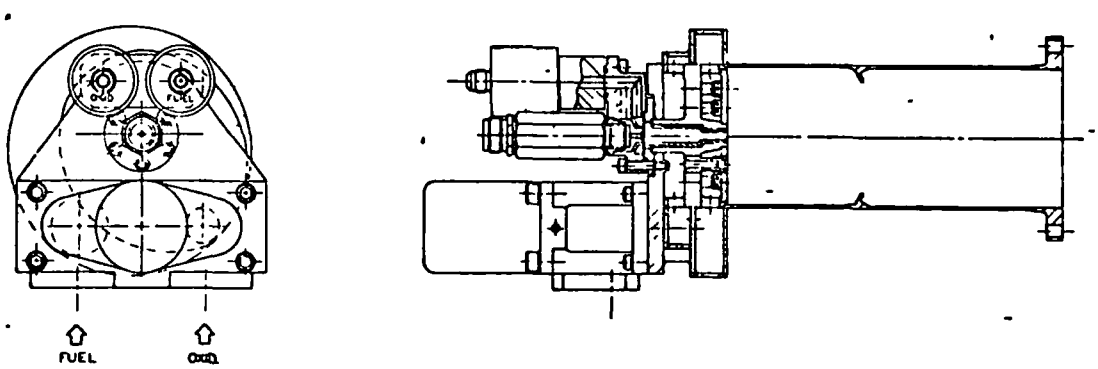

OXYGEN TURBOPUMP WEIGHT
NPSP (PSI
5
10
20
PUMP STAGES
ΔP (PSI)
3500
2500
1500
500
OXYGEN TURBOPUMP WEIGHT - LBS
500
100
50
10
5
2
5
10
50
100
OXYGEN TURBOPUMP FLOW RATE LB/SEC
NPSP (PSI)
5
10
20

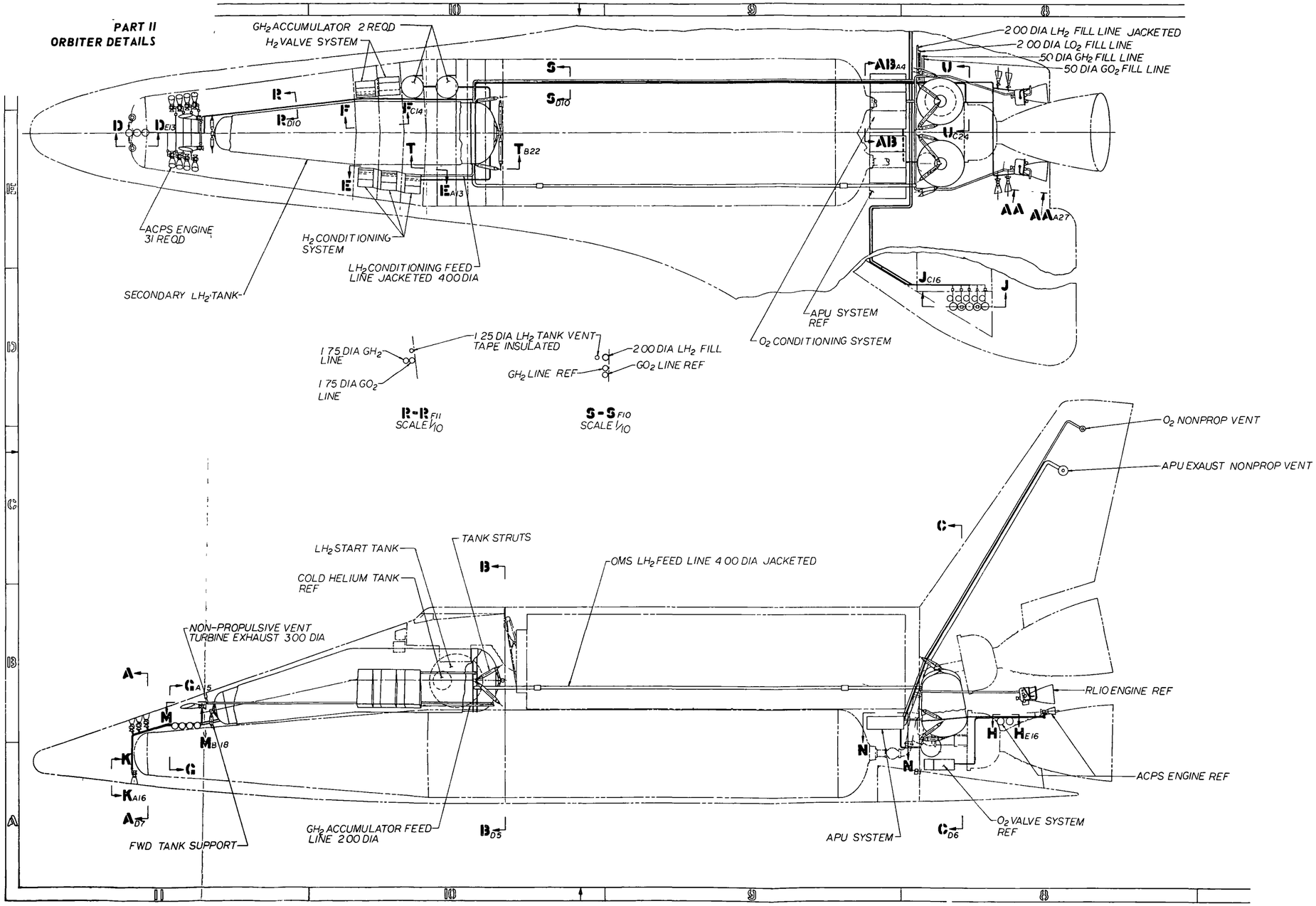
HEAT EXCHANGER

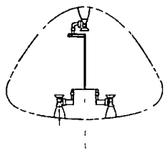
AUXILIARY PROPULSION PROPELLANT CONDITIONING SUBSYSTEM



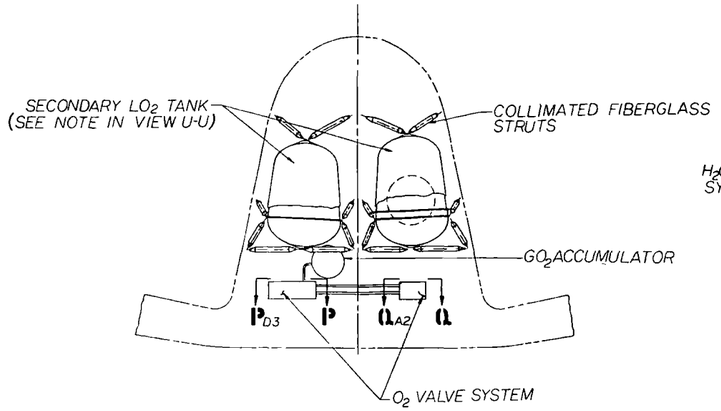
HIGH PRESSURE GAS GENERATOR SYSTEM



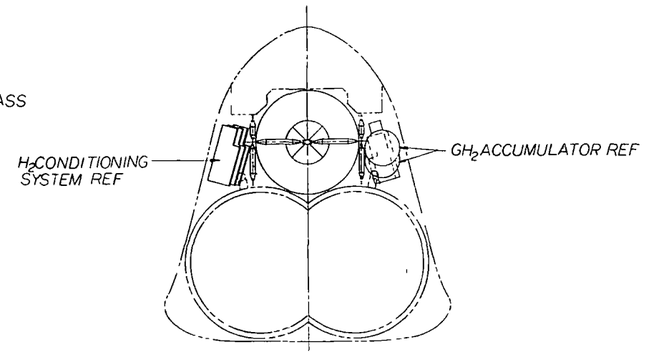

GH2 ACCUMULATOR 2 REQD
H2 VALVE SYSTEM
2 00 DIA LH2 FILL LINE JACKETED
2 00 DIA LO2 FILL LINE
50 DIA GH2 FILL LINE
50 DIA GO2 FILL LINE
ACPS ENGINE 31 REQD
H2 CONDITIONING SYSTEM
LH2 CONDITIONING FEED LINE JACKETED 400 DIA
SECONDARY LH2 TANK
APU SYSTEM REF
O2 CONDITIONING SYSTEM
1 75 DIA GH2 LINE
1 75 DIA GO2 LINE
1 25 DIA LH2 TANK VENT TAPE INSULATED
2 00 DIA LH2 FILL
GH2 LINE REF
GO2 LINE REF
R-RF11 SCALE 1/10
S-SF10 SCALE 1/10
O2 NONPROP VENT
APU EXAUST NONPROP VENT
LH2 START TANK
TANK STRUTS
COLD HELIUM TANK REF
OMS LH2 FEED LINE 4 00 DIA JACKETED
NON-PROPULSIVE VENT TURBINE EXHAUST 300 DIA
RL10 ENGINE REF
ACPS ENGINE REF
O2 VALVE SYSTEM REF
APU SYSTEM
GH2 ACCUMULATOR FEED LINE 2 00 DIA
FWD TANK SUPPORT



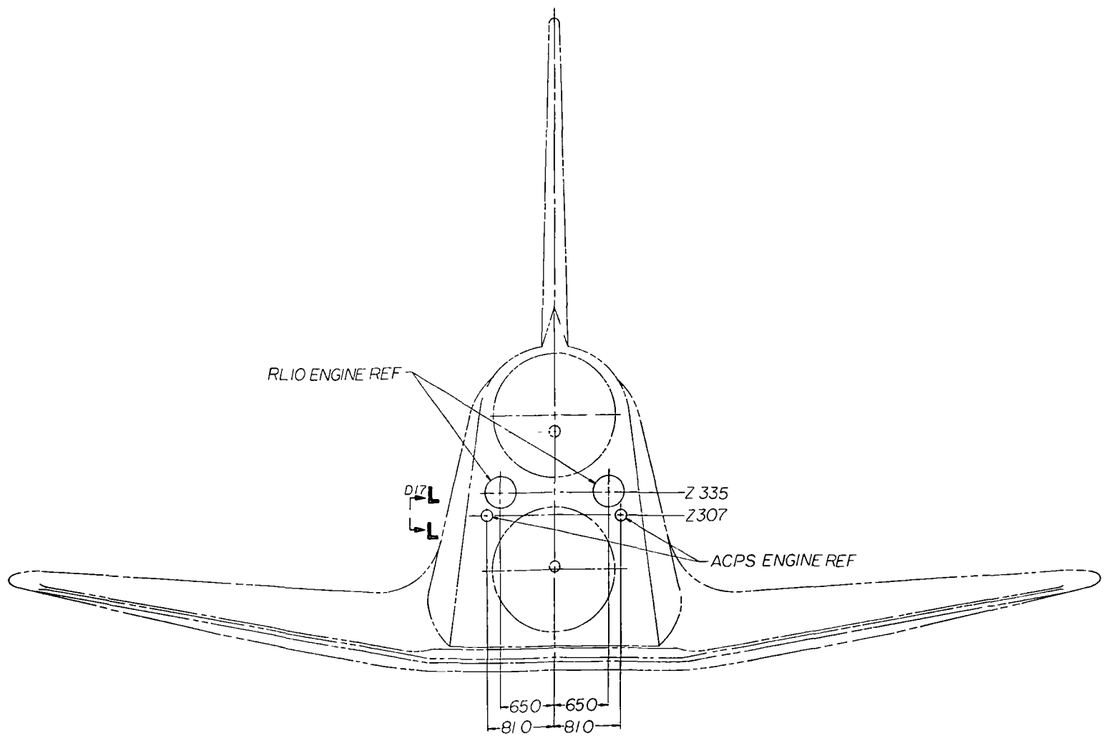
A - A_{A11}

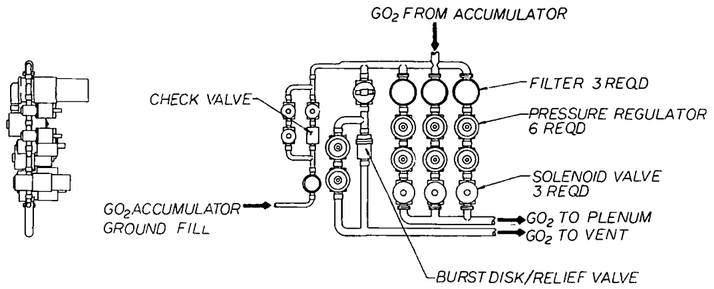


C - C_{A8}

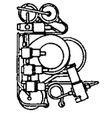


B - B_{A10}

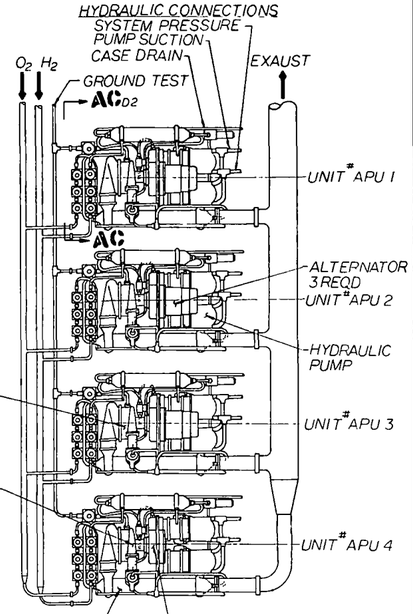




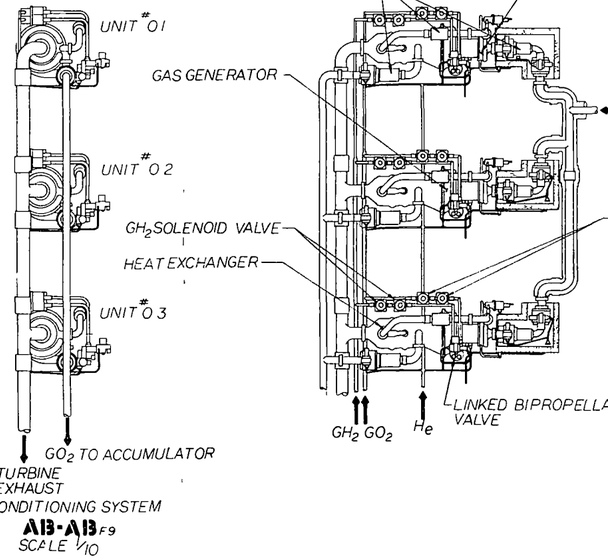
P-P $_{D6}$
SCALE 1/10



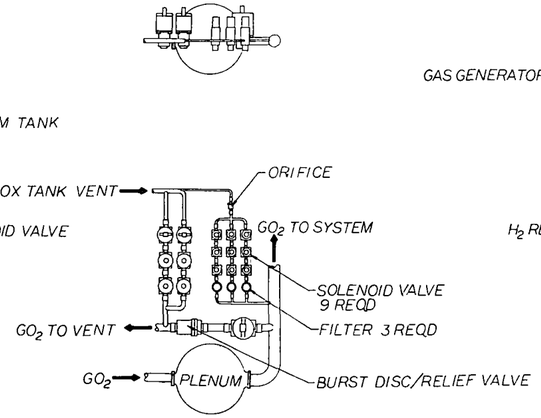
AC-AC $_{D1}$
SCALE 1/10



APU SYSTEM
N-N $_{A8}$
SCALE 1/10



AB-AB $_{F9}$
SCALE 1/10



Q-Q $_{D6}$
SCALE 1/10

DASH NO.	FIN ART QTY REQD	NEXT ASSY	USED ON APPLICATION

LOFT DATA
LAYOUT NO.
TOLERANCE UNLESS NOTED
.XX = ±.03
.XXX = ±.010
FINISH SPEC
CONTR NO.

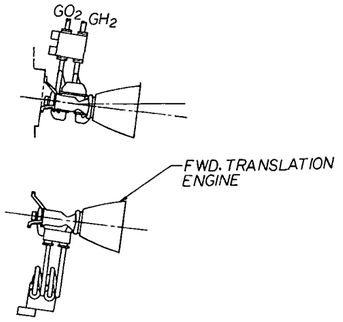
DR C E POLLARD 6-1-71
CHK. G.J.H.E. 8-1-71
STR
QUAL N.R.
PROP Dan Jones 6-1-71
Bob Pogue 8-1-71

McDONNELL DOUGLAS ASTRONAUTICS COMPANY EASTERN DIVISION
McDONNELL DOUGLAS CORPORATION

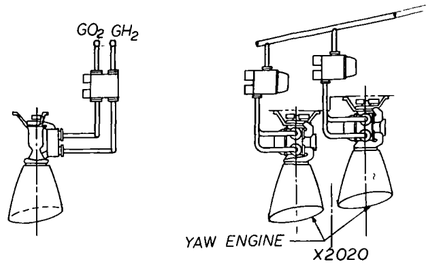
ACPS/OMS INSTALLATION

SIZE J | CODE IDENT NO. 76301 | 255BJ50146

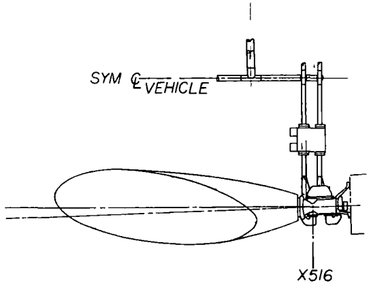
SCALE 1/20 | WT NOTED | LB | SHEET 1 OF 3



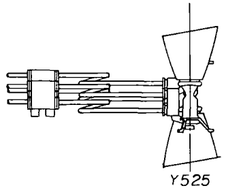
L - L_{B6}
SCALE 1/10

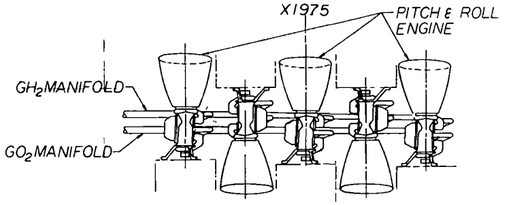


H - H_{B8}
SCALE 1/10

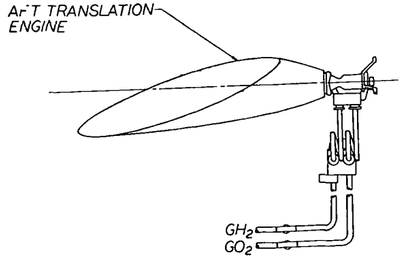


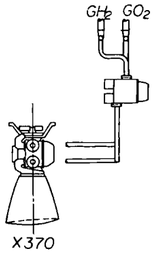
M - M_{B11}
SCALE 1/10

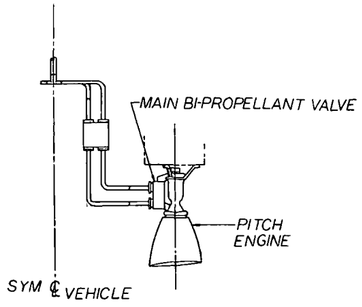




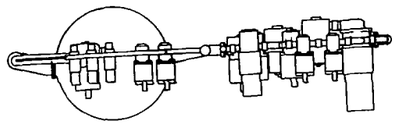
J - J_{D8}
SCALE 1/10



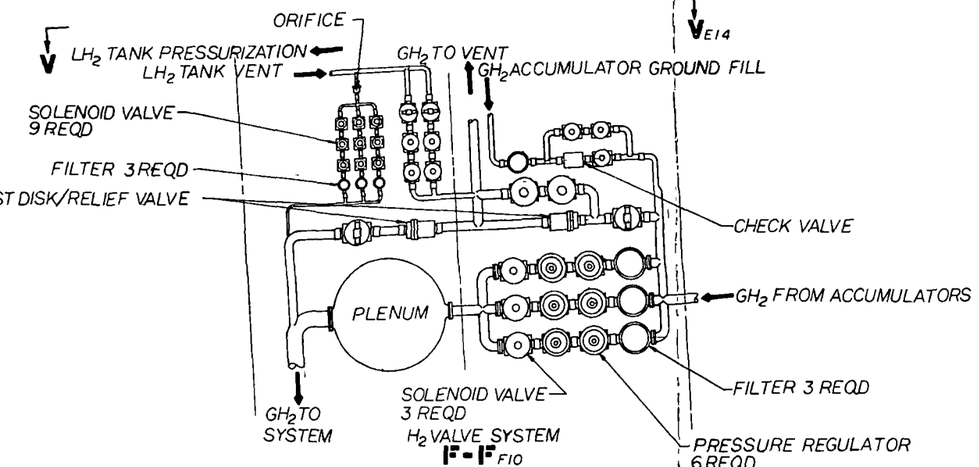




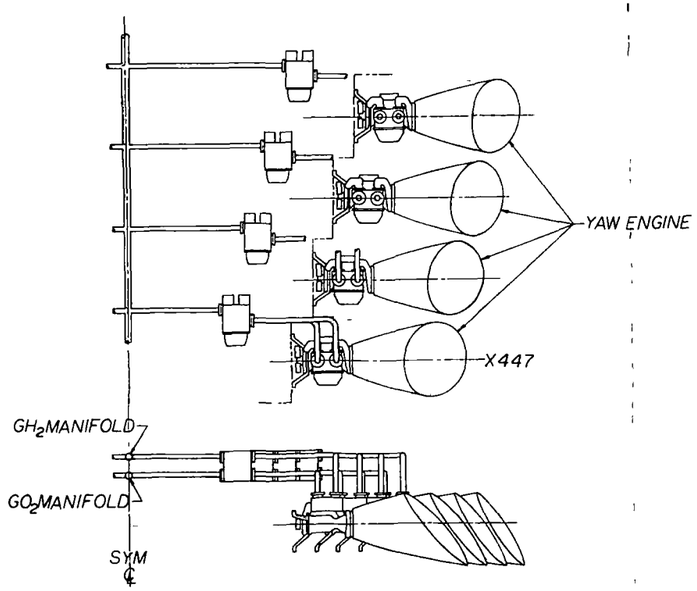
K - K_{A11}



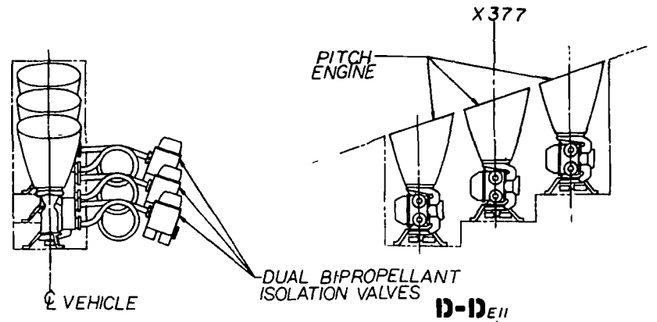
V - V E14
SCALE 1/10



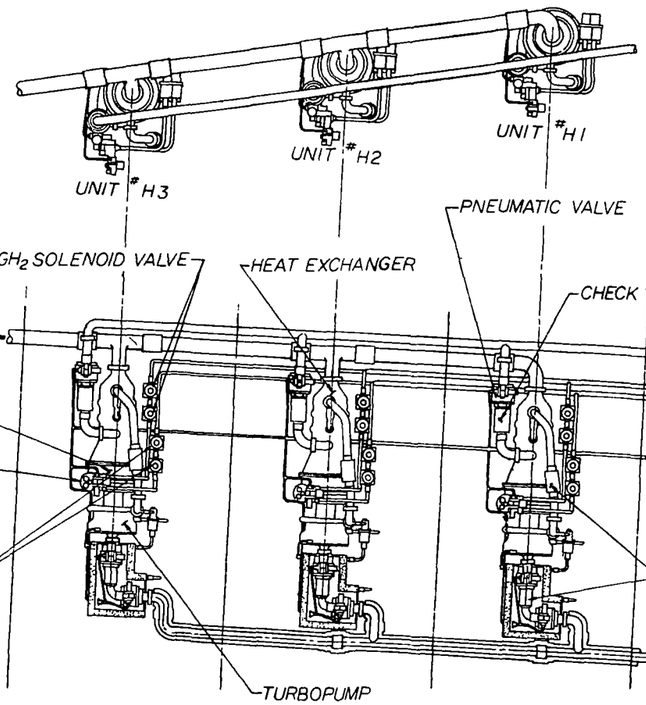
F - F F10
SCALE 1/10



G - G B11
SCALE 1/10



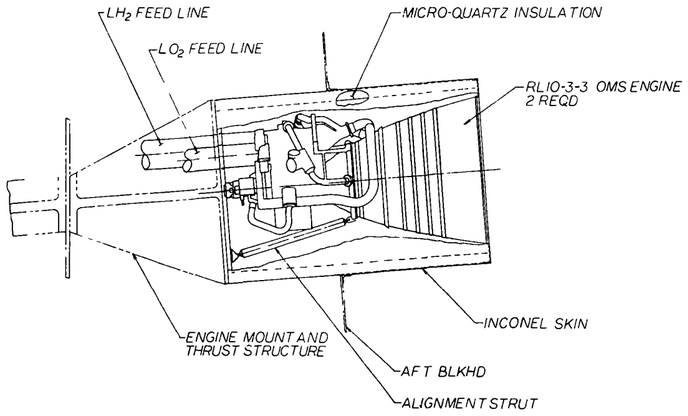
D - D E11
SCALE 1/10



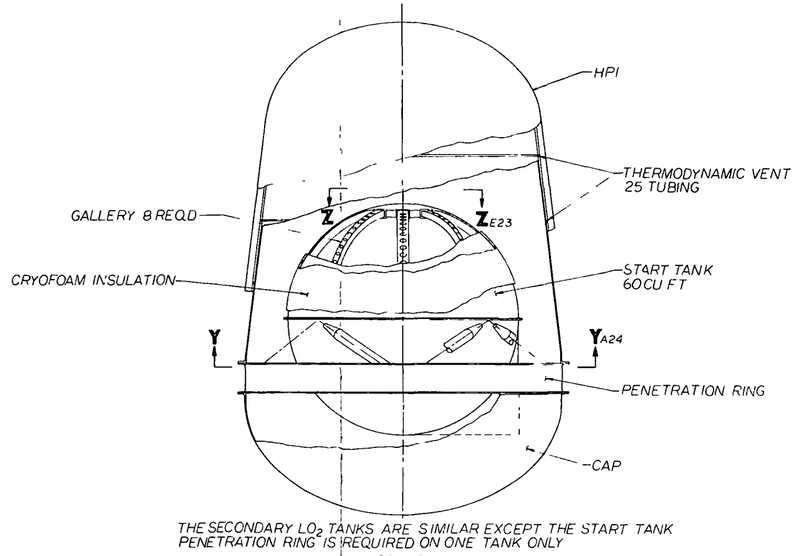
H2 CONDITIONING SYSTEM
E - E E10
SCALE 1/10

ACPS/OMS INSTALLATION
CODE IDENT NO. 76301
255BJ50146

2.8–25 B Continued

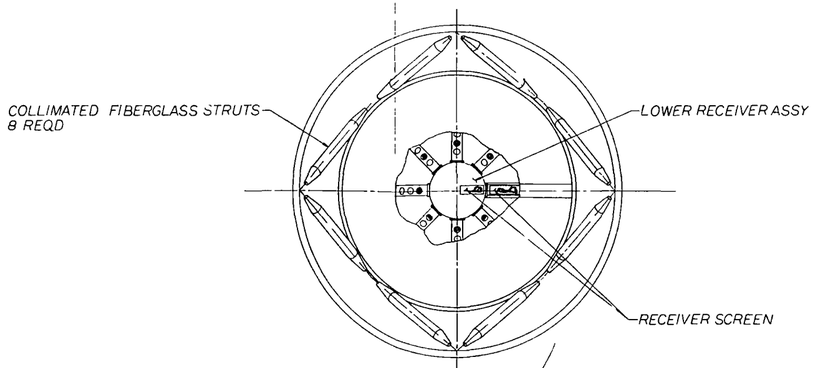


AA-AA $_{E8}$
SCALE 1/10

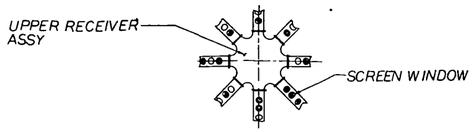


THE SECONDARY LO_2 TANKS ARE SIMILAR EXCEPT THE START TANK PENETRATION RING IS REQUIRED ON ONE TANK ONLY

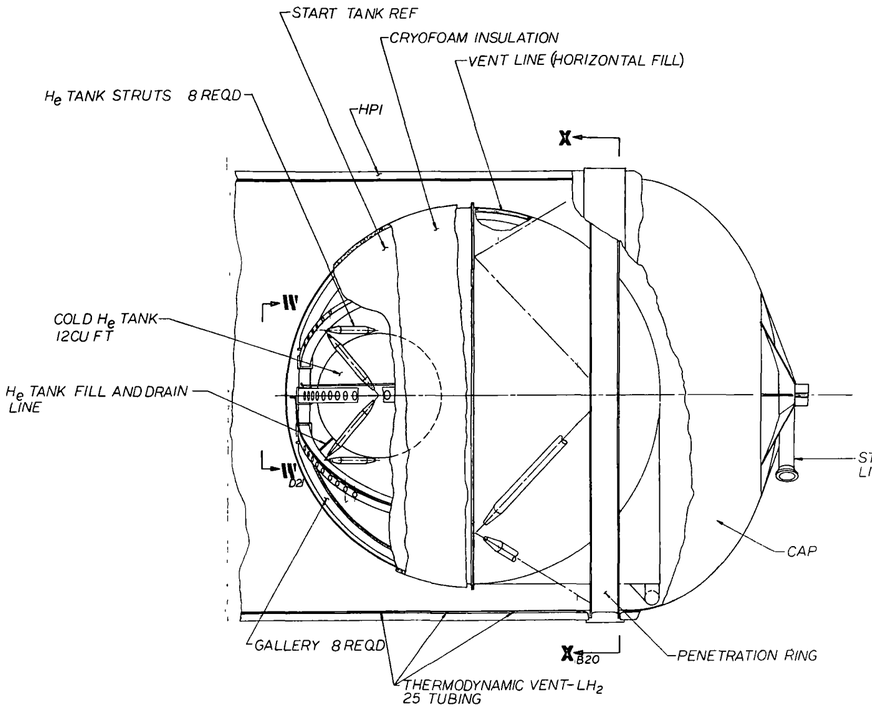
U-U $_{E8}$
SCALE 1/10



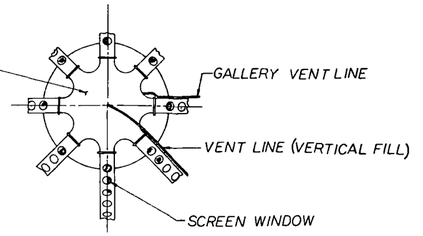
Y-Y $_{D24}$
SCALE 1/10



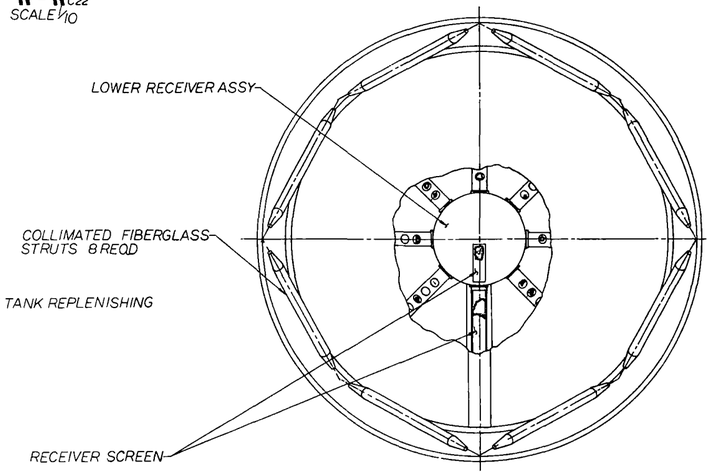
Z - Z D24
SCALE 1/10



T - T F10
SCALE 1/10



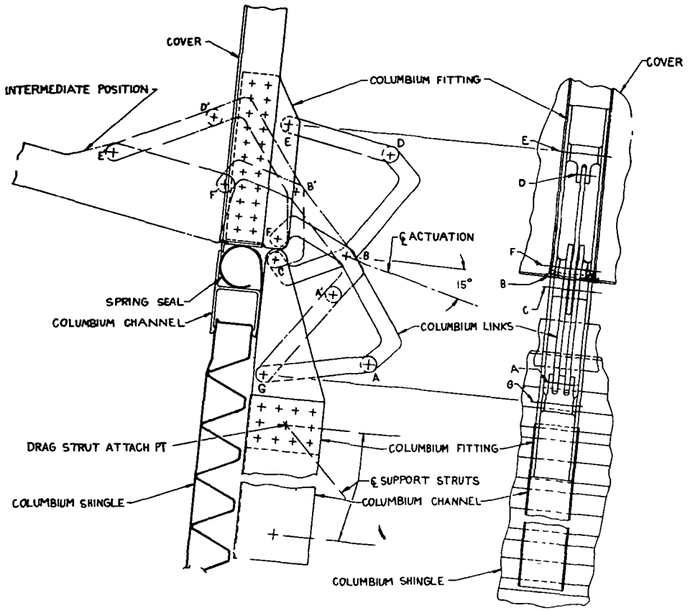
W - W C22
SCALE 1/10



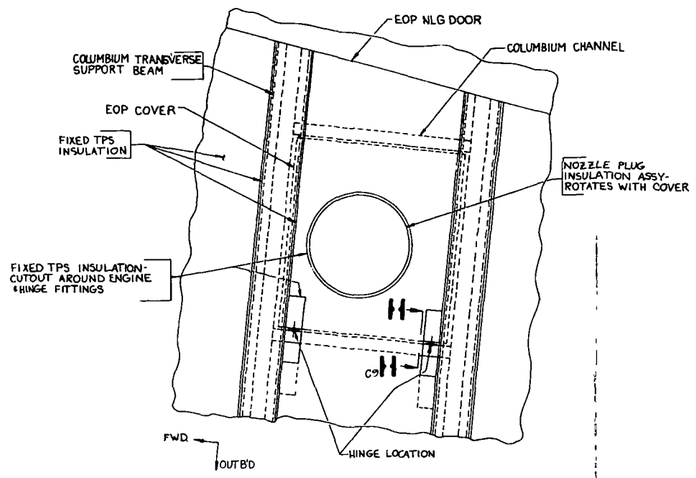
X - X B22
SCALE 1/10

2.8-25 C Continued

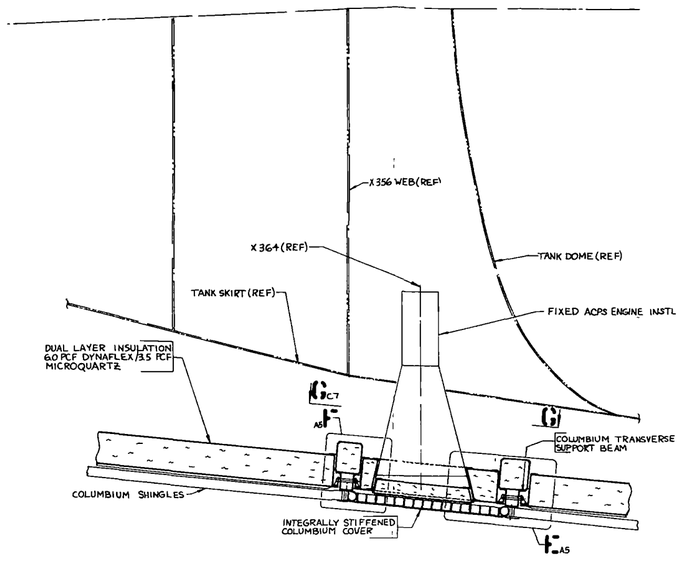
MCDONNELL DOUGLAS ASTRONAUTICS COMPANY – EASTERN DIVISION; MCDONNELL DOUGLAS CORPORATION		
ACPS/OMS INSTALLATION		
SIZE J	CODE IDENT NO. 76301	255BJ50146
SCALE NONE	WT	SHEET 3 OF 3
NOTES		

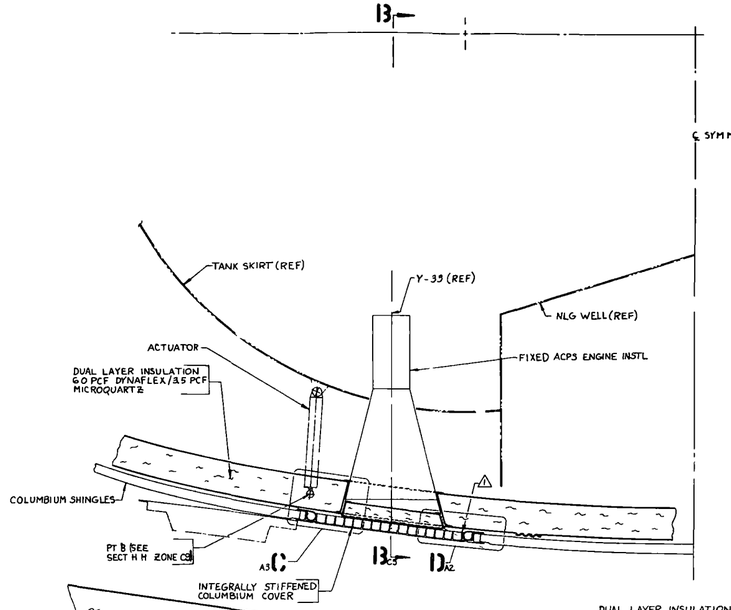


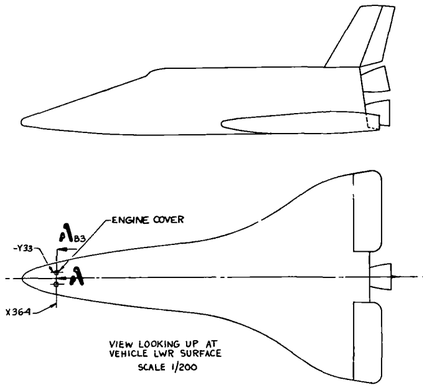
HH D7
SCALE FULL
-INSULATION DETAILS OMITTED FOR CLARITY-

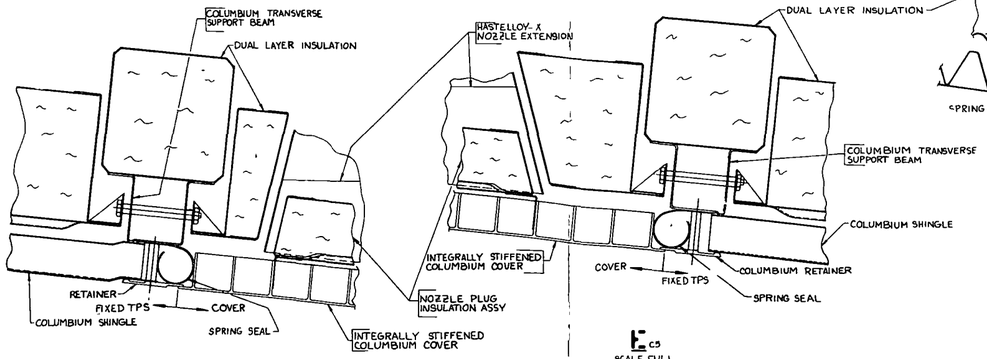


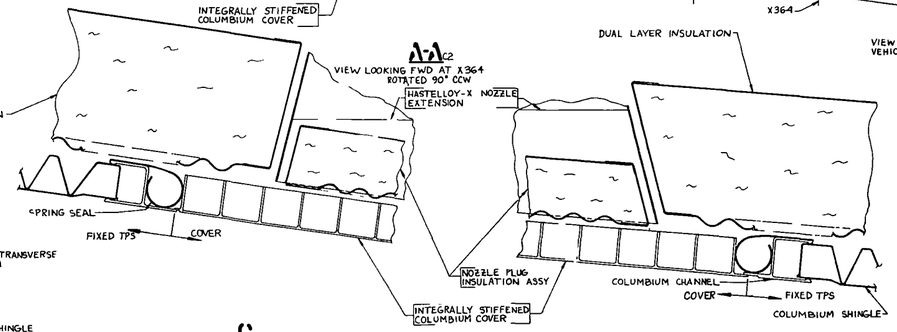
GG C5
VIEW LOOKING DOWN AT INSULATION
ACPS ENGINE OMITTED FOR CLARITY-











SCALE FULL

SCALE FULL

SCALE FULL

NOTES

△IF NECESSARY, THE FREE EDGE OF COVER MAY BE RESTRAINED BY UP LOCK MECHANISM

SECURITY CLASSIFICATION	DRAWING NUMBER	SH
U	255BJ50907	1

QTY REQD	QTY REQD FIND NO.	CODE IDENT NO.	PART OR IDENTIFYING NO.	DRAWING OR SPECIFICATION NO.	NOMENCLATURE OR DESCRIPTION	STOCK SIZE	MATERIAL OR MATERIAL CODE	NOTE NO.	ZONE
					PARTS LIST				

LOFT DATA	DR R VOGLER	9/21/71
LAYOUT NO.	CHK	
TOLERANCE UNLESS NOTED	STRESS	9/21/71
X = ± 1	OR	9/21/71
.XX = ± .03	STD	9/21/71
.XXX = ± .010		
FINISH SPEC		9/21/71
CONTR NO.		

DASH NO.	ASSY QTY REQD	ART	NEXT ASSY	USED ON APPLICATION

McDONNELL
ST LOUIS, MISSOURI

ACPS ENGINE COVER (TPS)-DOWN FIRING

SIZE	CODE IDENT NO.	255BJ50907
J	76301	

SCALE 1/4 & NOTED | WT | LB | SHEET 1 OF 1

DRAWING NUMBER 255BJ50907